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ANALYSIS USING THE NCEL R..(U) SYSTECH CORP XENIA OH
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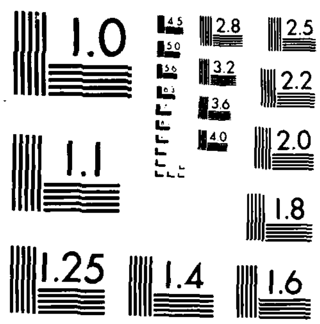

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August 1986
An Investigation Conducted
By SYSTECH Corporation
Sponsored By Naval Facilities
Engineering Command

NCEL
Contract Report

FINAL REPORT: RDF CO-FIRING COST/BENEFIT ANALYSIS USING THE NCEL RDF COST MODEL VOLUME I, PROJECT RESULTS

ABSTRACT The object of this effort was to determine the cost effectiveness of co-firing RDF in existing Navy boilers. The cost-benefit analysis was performed using the NCEL RDF Cost Model and site specific boiler and cost data acquired from four naval activities that were determined to have the highest probability of successful co-firing. The cost effectiveness was measured by the savings to investment ratio (SIR) and computed over a range of cost and operating conditions to determine optimum RDF co-firing scenarios for each facility. Based on present laid-down coal costs and solid waste disposal charges, no set of operating conditions could be identified wherein the use of either co-fired RDF-3 or RDF-5 could be economically justified. Volume I presents the report; Volume II contains appendixes, and Volume III is the terminal manual of RDF cost model.

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The object of this effort was to determine the cost effectiveness of co-firing RDF in existing Navy boilers. The cost-benefit analysis was performed using the NCEL RDF Cost Model and site specific boiler and cost data acquired from four naval activities that were determined to have the highest probability of successful co-firing. The cost effectiveness was measured by the

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ACKNOWLEDGEMENT

This report documents the work performed under Delivery Order ZZ07, Cost/Benefit Analysis of Co-Firing Refuse-Derived Fuel (RDF) in Retrofitted, Existing Navy Boilers Using the NCEL RDF Cost Model. This delivery order was executed under U.S. Navy Contract No. N00123-83-D-0149. The Contracting Officer was Mr. Andrew Lendacky, and the Project Engineer was Mr. R. M. Roberts, Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California.

SYSTECH gratefully acknowledges the guidance and support of Mr. Roberts in the performance of this work. SYSTECH also wishes to thank the personnel of Naval Amphibious Base, Little Creek, Virginia; Naval Shipyard, Bremerton, Washington; Naval Submarine Base, Bangor, Washington; and Marine Corps Air Station, Cherry Point, North Carolina, for the effort they extended to provide us with the data necessary to perform this work effort. Their cooperation was greatly appreciated.

ORGANIZATION OF REPORT

This report has been prepared in three volumes. Volume I contains the results of the cost-benefit analysis using the NCEL RDF Cost Model. Volume II contains the referenced appendices. These appendices contain program listings, modification details, complete program outputs for each activity, and activity data in the form of completed data questionnaires and telephone logs. Volume III contains the directions for operating the NCEL RDF Cost Model.

SECTION 1.0
INTRODUCTION

1.1 BACKGROUND

The Navy has been mandated to reduce its consumption of imported fossil fuels through the substitution of alternate fuels such as refuse-derived fuels (RDF), coal, peat, wood chips, landfill gas, and hybridized compositions such as coal/oil mixtures. A number of projects have been completed or are now underway to realize that goal. The Naval Civil Engineering Laboratories (NCEL) has invested considerable effort in the study of the RDF technology. This has included the determination of optimum heat recovery incinerator (HRI) design, the systemization of HRI application economics, and the study of RDF properties and processing. The current effort concludes the NCEL's research in RDF by providing a cost benefit analysis of utilizing RDF in existing Navy shore facility boilers.

Several demonstration projects have been conducted to determine if selected forms of RDF can be successfully co-fired in appropriately configured boilers that have not been designed for such fuels. Although in some cases the results were not technically conclusive, the majority of the information indicates that it is feasible to co-fire RDF and coal if certain modifications are made to the boiler system. In other cases, extensive modifications were required. Therefore, it was not clear at the conclusion of these test burns whether RDF co-firing is cost effective.

The NCEL RDF Cost Model was developed to establish a methodology for determining the potential cost benefits of co-firing RDF in Navy boilers ashore under various operating and economic conditions. The model was intended to evaluate co-firing scenarios under all possible, reasonable combinations of RDF types, shore facility boiler designs, firing conditions, and fuel market conditions. The model was developed using data previously developed by NCEL, other engineering and cost data available in the open literature, and data from vendors and engineering firms that supply and erect such facilities.

1.2 OBJECTIVES

The objective of this effort was to determine the cost effectiveness of co-firing RDF in existing Navy boilers. The cost-benefit analysis was to be performed using the NCEL RDF Cost Model and site specific boiler and cost data acquired from naval installations that were previously determined to have the highest probability of successful co-firing. Prior to performing the analysis, the model was carefully reviewed for errors, omissions, and appropriateness for the candidate sites. Input variables were evaluated over a reasonable range to determine the sensitivity of the model to these changes.

The cost effectiveness was measured by the savings to investment ratio (SIR) and computed over a range of cost and operating conditions to determine the optimum RDF co-firing scenarios for each facility.

1.3 APPROACH

The Naval activities evaluated by the model were selected on the basis of the type of boiler currently in use, its current conventional fossil fuel type, and the age of the boiler. This information was obtained from reports prepared for NCEL by VSE (Reference 1), Gilbert (Reference 2), and WETCO (Reference 3). Operational and economic data were obtained from each facility by questionnaires and by telephone conversations with facility operators and engineers. The completed questionnaires and telephone logs are presented in Appendices A and B, respectively.

The model was run for each activity to estimate the cost effectiveness at current operating and economic conditions. A sensitivity analysis was then performed to rank the relative impact of the various operating and economic data inputs on the resultant SIR. To do this, the model was exercised over a reasonable range of values for those inputs. The range was based on data obtained from RDF and coal co-firing evaluations, RDF characterization studies, and other economic evaluations. From the sensitivity analysis results, a set of optimum conditions was established and a best case evaluation was made.

1.4 MODEL REVIEW

1.4.1 Model Description

The NCEL RDF Cost Model is based on the Microsoft® Multiplan® spread sheet program. It can be operated on IBM PC, XT, AT, and compatible computers with single or dual disk drives. Although a hard disk drive is not essential, it does greatly enhance the speed of executing the program.

The model consists of seven interactive spread sheets saved as individual files. Table 1-1 lists the names and functions of each sheet. The first sheet accepts input data for one activity. The input data consists of: boiler design and current operating conditions, RDF specifications, and economic data, such as current conventional fuel costs ($/ton) and waste disposal rates ($/ton, tons per year [TPY]). Sheets two and three access the input data from sheet one to calculate the various boiler flow rates, fuel requirements, and operating costs for both co-firing and coal only conditions. The fourth, fifth, and sixth sheets are formatted to printout the intermediate flow rates and operating conditions from sheet two. The seventh sheet is used to print out a summary and comparison of the operational and economic results for the co-firing and coal only cases which were computed in sheet three. Sheet seven is utilized for comparison of the various operating scenarios at each activity. Figure 1-1 is a flow schematic of the model.

TABLE 1-1. MULTIPLAN® SPREAD SHEET FILE NAMES AND DESCRIPTIONS

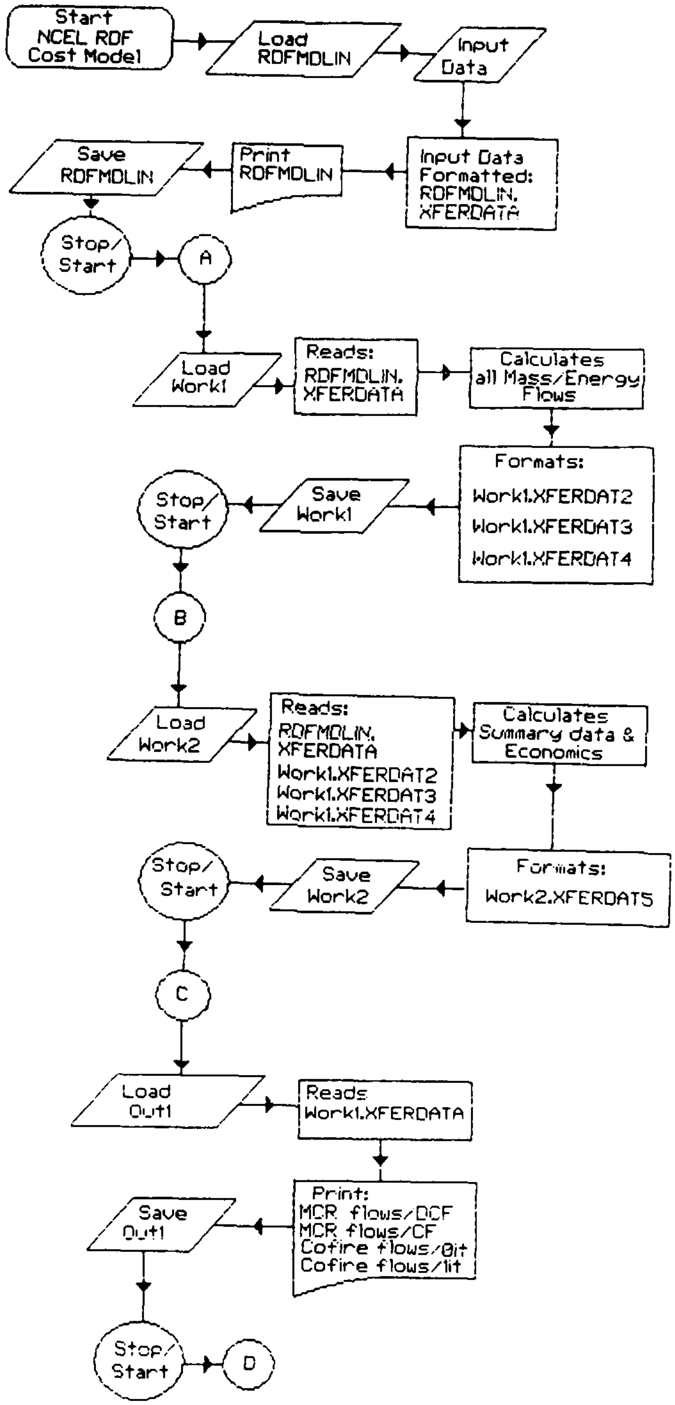
Sheet no.	File name	Description
1	RDFMDLIN	Contains the activity input data
2	Work 1	Calculates intermediate co-firing operational data
3	Work 2	Calculates final co-firing operational and economic data
4	Out 1	Prints out intermediate co-fire data
5	Out 2	Prints out intermediate co-fire data
6	Out 3	Prints out intermediate co-fire data
7	Out 4	Prints out final co-fire operational and economic data

The "User Manual for the Refuse-Derived Fuels (RDF) Model," prepared by the L.I. Dimmick Corporation (Reference 4), provides complete instructions for operating the model. The modifications made to the model do not affect how it is operated.

1.4.2 Technical Description

To calculate the final set of RDF co-firing operating and economic results, the model first calculates various intermediate mass and energy flow rates from the input data. These mass and energy flow rates and the resultant boiler efficiencies are calculated for both the design conventional fuel (DCF) and for the current conventional fuel (CF) at the boiler's maximum continuous rating (MCR). Similarly, flow rates and efficiencies are calculated for RDF co-firing at an RDF-derated MCR, for an average boiler load, and for the minimum level of stable operation (or maximum turndown [TD]). Cofire MCR and TD flow rates are calculated to estimate the achievable steam supply range. This co-fire steam range is then compared to the actual steam demand. When the actual steam demand is within the co-fire steam supply range, full credit for avoided CF costs is applied. When the actual demand is above the co-fire range, the model assigns a partial conventional fuel cost savings. When the demand is below the range, co-firing is not possible and no CF cost savings are realized.

Once the final co-fire capabilities and flow rates are established, economic factors are evaluated. These evaluations are based primarily on retrofit and operations and maintenance (O&M) costs. The SIR is calculated



Fig·· e 1-1. NCEL RDF cost model flow diagram.

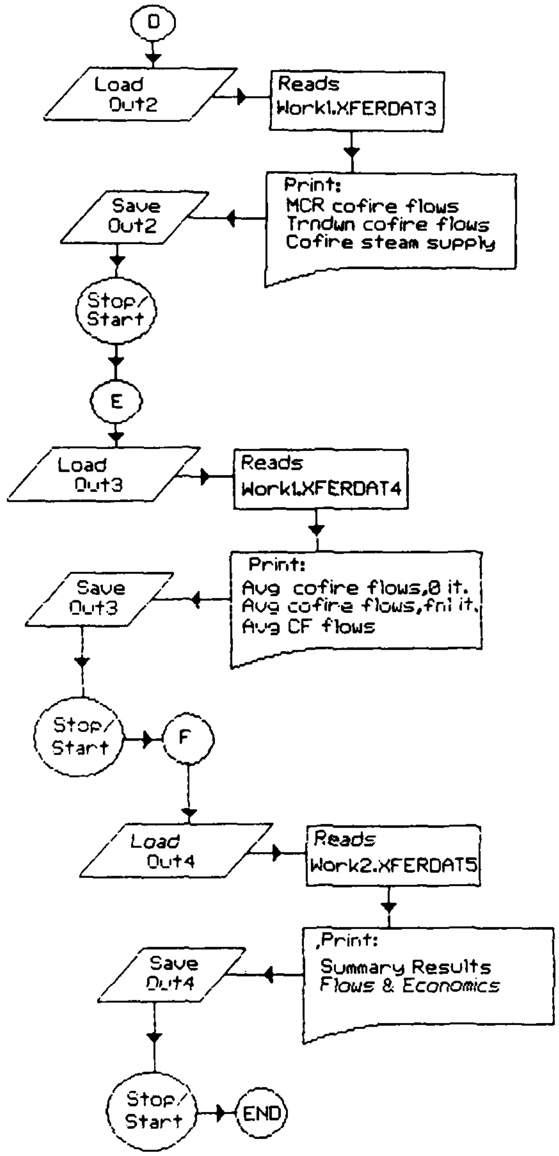


Figure 1-1. (continued).

following NAVFAC P-442 Type I economic analysis guidelines (Reference 5). The SIR is calculated two ways: with and without a credit for the avoided cost of solid waste disposal. The credit for solid waste disposal is based on the assumption that the Navy may be able to dispose (at no or low cost) of half its solid waste stream at the RDF production facility.

1.4.3 Modifications to Model

Table 1-2 lists the model algorithms which were modified. In general, the changes were prompted by the need for the model to address more adequately RDF-5 utilization factors. The assumptions used in the original model were frequently based solely on RDF-3 fuel and combustion characteristics and RDF-3 use requirements, thereby making the model inappropriate for RDF-5 applications. For the most part, the modifications consisted of inserting logic gates which check for the type of RDF to be considered and then applying RDF-3 or RDF-5 factors accordingly. The algorithms and details of each modification are presented in Appendix C. Appendix D contains a complete listing of the Multiplan® formulas.

TABLE 1-2. AREAS OF THE MODEL WHICH WERE MODIFIED

- Air pollution control efficiency algorithm
- Maximum co-fire turn down algorithm
- Co-fire excess air algorithm
- RDF storage algorithm
- RDF delivery (from storage to boiler) algorithm
- Ash handling system algorithm
- RDF delivery to the site algorithm
- Flyash fraction algorithm
- Savings: Investment ratio algorithm
- Input data for boiler efficiency algorithm

SECTION 2.0
ACTIVITY SELECTION AND INPUT DATA COLLECTION

2.1 ACTIVITY SELECTION

The activity selected for this evaluation were screened from other Navy shore-based activities on the basis of their boiler characteristics. Studies by Gilbert (Reference 2) and VSE (Reference 1), which were summarized by Wetco (Reference 3), evaluated Navy boilers on the basis of their technical compatibility with various RDF co-firing scenarios. RDF-3 and RDF-5 were considered to be the most viable forms of RDF for co-firing situations, and boilers designed for both coal and oil were considered to be technically capable of utilizing these fuels. The final selection was ultimately based on the overall economics of anticipated retrofit costs, but numerous technically qualified, low retrofit cost candidates were eliminated from further consideration due to their age. Many otherwise technically qualified, stoker-fired boilers built in the late 1940s were considered to have a limited serviceble life expectancy and, therefore, are not considered suitable for RDF implementation under this program. Four activities were ultimately selected. The power plant at each activity is relatively new (one is currently under construction); each has stoker-fired boilers and is technically suited to co-firing RDF-5. Table 2-1 lists the activities.

TABLE 2-1. ACTIVITIES SELECTED FOR THE COST BENEFIT ANALYSIS

1. Naval Amphibious Base Little Creek
   Norfolk, Virginia

2. Puget Sound Naval Shipyard
   Bremerton, Washington

3. Naval Submarine Base Bangor
   Bremerton, Washington

4. Marine Corps Air Station
   Cherry Point, North Carolina

2.2 INPUT DATA COLLECTION

The economic feasibility of co-firing RDF at each of the selected activities, as determined by the RDF Cost Model, is based primarily upon site specific operational and design information. This information was obtained from each of the respective activities in response to a questionnaire (Figure 2-1) and follow-up telephone inquiries (Appendix B). The questionnaire was derived from the input listings of the cost model. Requests for additional non-input information were incorporated into the questionnaire to aid in cross-checking intermediate model calculations and to document actual operating conditions.

As anticipated, all of the questionnaires were returned, but each had gaps in the requested information (Appendix A). Various means were employed to acquire the missing, yet required, items of information. Data for fuel characteristics were obtained from engineering reference manuals. If design operating specifications were not available, estimates were made based on current conditions. Other items, such as particulate emissions and thermal efficiencies, were derived from test reports submitted by the activities. The majority of the missing information was acquired via follow-up telephone inquiries.

NAVAL BASE
BLD #
BOILER #
PRIMARY CONTACT PERSON
TITLE
PHONE #

DESIGN FUEL INFORMATION

DESIGN TOTAL FUEL VALUE TO BOILER AT MCR (MAXIMUM CONTINUOUS RATING) (BTU/HR)
DESIGN FUEL TYPE
HIGHER HEATING VALUE OF DESIGN FUEL (BTU/LB)
FRACTIONAL ASH CONTENT OF DESIGN FUEL, AS RECEIVED
FRACTIONAL MOISTURE CONTENT OF DESIGN FUEL
HYDROGEN MASS FRACTION OF AS RECEIVED DESIGN FUEL
SPECIFIC HEAT OF DESIGN FUEL
DESIGN CARBON LOSSES AS PERCENT OF MAXIMUM FUEL VALUE TO BOILER AT MCR
DESIGN RADIATION LOSSES AS PERCENT OF MAXIMUM FUEL VALUE TO BOILER AT MCR
DESIGN TEMPERATURE OF DESIGN FUEL AT BOILER BOUNDARY (DEG F)
DESIGN EXCESS AIR REQUIRED FOR DESIGN FUEL AT MCR (%)

CURRENT FUEL INFORMATION
CURRENT FUEL TYPE
CURRENT FUEL VALUE TO BOILER AT MCR (BTU/HR)
(FOR THE FOLLOWING, SUPPLY FUEL ANALYSIS REPORT, IF AVAILABLE)
HIGHER HEATING VALUE OF CURRENT FUEL (BTU/LB)
FRACTIONAL ASH CONTENT OF CURRENT FUEL, AS-RECEIVED
FRACTIONAL MOISTURE CONTENT OF CURRENT FUEL
HYDROGEN MASS FRACTION OF AS-RECD CURRENT FUEL
SULFUR MASS FRACTION OF AS-RECD CURRENT FUEL
SPECIFIC HEAT OF CURRENT FUEL
CURRENT CARBON LOSSES AS PERCENT OF MAXIMUM FUEL VALUE TO BOILER AT MCR
CURRENT RADIATION LOSSES AS PERCENT OF MAXIMUM FUEL VALUE TO BOILER AT MCR
TEMPERATURE OF CURRENT FUEL AT BOILER BOUNDARY (DEG F)
EXCESS AIR REQUIRED FOR CURRENT FUEL AT MCR (%)
MAXIMUM BOILER TURNDOWN ACHIEVABLE WITH CURRENT FUEL (%)
EXCESS AIR REQUIRED FOR CURRENT FUEL AT NEAR MAXIMUM TURNDOWN (%)

BOILER AND EQUIPMENT INFORMATION
FOR THE FOLLOWING, GIVE THE MANUFACTURER, EQUIPMENT DESCRIPTION AND RATED CAPACITIES OR THROUGHPUTS
FUEL FEED SYSTEM
GRATE SYSTEM
ASH HANDLING SYSTEM
MULTICLONES OR CYCLONES
SCRUBBERS
ESP
BAGHOUSE

Figure 2-1. RDF cost model input data questionnaire.

IS THE BOILER EQUIPPED WITH :

AN ID FAN	-------------------------
SOOTBLOWERS FOR THE CONVECTIVE	-------------------------
AN ECONOMIZER	-------------------------
SOOTBLOWERS FOR THE ECONOMIZER	-------------------------
WHAT TYPE OF ECONOMIZER TUBES?	-------------------------

OPERATIONS INFORMATION

AVAILABILITY OF EXISTING BOILER FIRED WITH CURRENT FUEL (%)	-------------------------
DOES ADEQUATE BACKUP CAPABILITY EXIST	-------------------------
DOES BOILER HAVE A HISTORY OF SLAGGING	-------------------------

FOR THE FOLLOWING, SUPPLY TEST REPORTS ON PARTICULATE EMISSIONS COMPLIANCE OR BOILER EFFICIENCY TESTS, IF AV

APPLICABLE PARTICULATE EMISSIONS STANDARD	-------------------------
ACTUAL PARTICULATE EMISSIONS	-------------------------
STACK TEMPERATURE (DEG F)	-------------------------
STACK VOLUMETRIC FLOW RATE (ACFM)	-------------------------
AIR TEMP AT FD OR AIR-HEATING INLET (DEG F)	-------------------------
PREHEAT COMBUSTION AIR TEMP (DEG F)	-------------------------
FUEL TEMP AT BOILER BOUNDRY (DEG F)	-------------------------
BOTTOM ASH TEMP AT BOILER BOUNDARY (DEG F)	-------------------------
FLY ASH TEMP AT BOILER BOUNDARY (DEG F)	-------------------------

ECONOMIC INFORMATION

BASIC UNBURDENED OPERATOR WAGERATE ($/HR)	-------------------------
BURDENING ON BASIC WAGE RATE, A MULTIPLIER	-------------------------
COST OF CONVENTIONAL FUEL ($/TON)	-------------------------
COST OF ELECTRICITY ($/KWH)	-------------------------
DISPOSAL COST FOR ASH ($/TON)	-------------------------

STEAM DEMAND BY SHIFT BY SEASON BY DAY, AVERAGE HOURLY (BTU/HR)

SUMMER	SHIFT 1	SHIFT 2	SHIFT 3
MON-FRI	----------------	----------------	----------------
SAT	----------------	----------------	----------------
SUN	----------------	----------------	----------------
WINTER			
MON-FRI	----------------	----------------	----------------
SAT	----------------	----------------	----------------
SUN	----------------	----------------	----------------
SPRING AND FALL			
MON-FRI	----------------	----------------	----------------
SAT	----------------	----------------	----------------
SUN	----------------	----------------	----------------

DISPOSAL COST FOR MUNICIPAL SOLID WASTE OR BASE WASTE ($/TON)	-------------------------
PROJECTED FUTURE DISPOSAL COST FOR MUNICIPAL SOLID WASTE OR BASE WASTE	-------------------------
PROJECTED LIFE OF LOCAL LANDFILL(S)	-------------------------
ANNUAL GENERATION RATE OF BASE WASTES (TON/YR)	-------------------------

NAME AND PHONE NUMBER OF CONTACT PERSON IN CHARGE OF:

NAVAL WASTE DISPOSAL ACTIVITIES	NAME -------------------------	PHONE # ------
LOCAL COMMUNITY OR COUNTY SOLID WASTE AUTHORITY	NAME -------------------------	PHONE # ------

Figure 2-1. (continued).

SECTION 3.0
CASE STUDY COST/BENEFIT ANALYSIS

3.1 INTRODUCTION

The NCEL RDF Cost Model can be used to determine the preliminary feasibility of co-firing RDF in an existing coal-fired Navy boiler. As with any preliminary evaluation, there is uncertainty in the results due to the use of input values that are not directly obtainable from historical operating data or values that are subject to change over time. These inputs must than be based on engineering judgment or other information sources. It is therefore important to know how the model will react to variations in the input data. For example, if the analysis indicates the project is not currently feasible, but if landfill tipping fees are projected to rise appreciably in the near future, it is important to know the effect such changes will have on the final analysis.

The sensitivity analysis also has the advantage of determining what the operating and economic conditions must be before the co-firing project can be economically feasible. To determine the most economic arrangement for co-firing at each activity, the model was exercised over a range of possible operating and economic conditions by changing individual inputs on a one-at-a-time basis. To establish a mathematical basis for calculating these conditions, a "baseline" case was established. The baseline provides a set of activity parameters which can be held constant as other individual variables are changed. In general, the baseline case utilizes the operating and economic conditions reported for each facility. It also uses the characteristics of a good quality RDF-5 which is essentially free, having only a delivery cost of $2/ton associated with it. Since free RDF is an unrealistic scenario, the reader is cautioned not to make comparisons to the baseline case. Again, it is merely a mathematical starting point. Table 3-1 lists the baseline input values for each activity.

3.2 INPUT DATA REVIEW

Generically, the four activities that were evaluated are essentially the same. They all have stoker-fired boilers with pneumatic ash handling systems. Each activity has a substantial seasonal steam variation, and the capital costs for retrofitting the units to co-fire RDF vary essentially only with the scale of RDF input. However, there are specific local factors that set them apart from each other; those factors will be the reason for differences between the activities in the sensitivity analysis. These differences include solid waste disposal and generation rates, conventional fuel cost and heating value, and ash disposal cost. For this analysis, base generated solid waste is assumed to approximate the composition of municipal solid waste (MSW). The base waste is presumed to consist of office, housing, and food wastes; minimal industrial/manufacturing type wastes; and no

TABLE 3-1. INPUT DATA UTILIZED FOR THE BASELINE EVALUATION AT EACH FACILITY

			Activity			
(1)	Input Data	Units	Cherry Point	Puget Sound	Little Creek	Bangor
*	FRACTIONAL MOISTURE CONTENT OF AS RCVD RDF		0.2	0.2	0.2	0.2
*	FRACTIONAL ASH CONTENT OF AS RCVD RDF		0.1	0.1	0.1	0.1
	HYDROGEN MASS FRACTION OF MAF RDF		0.07	0.07	0.07	0.07
*	RDF COST ($0/T + $2/T delivery)	$/TON	2	2	2	2
	RDF BULK DENSITY	PCF	35	35	35	35
	RDF SIZE (PASSES THROUGH SCREEN OPENING)	INCHES	1.5	1.5	1.5	1.5
*	FRACTION OF HIGHER FUEL HEATING VALUE SUPPLIED TO BOILER BY RDF		0.4	0.4	0.4	0.4
	FRACTIONAL MOISTURE CONTENT OF AS RCVD CF		0.045	0.12	0.03	0.051
	FRACTIONAL ASH CONTENT OF AS RCVD CF		0.06	0.07	0.07	0.075
*	FRACTIONAL EXCESS-AIR NORMALLY REQUIRED FOR 100% CF AT MCR		0.17	0.3	0.33	0.32
	TOTAL HIGHER FUEL VALUE TO BOILER WHEN USING 100% CF AT MCR	BTUH	9.10E+07	1.73E+08	1.02E+08	7.20E+07
	HIGHER HEATING VALUE OF CF	BTU/LB	14724	10500	13800	12300
	RADIATION LOSSES AS FRACTION OF DTOTHHVCF		0.0074	0.0041	0.0053	0.0052
	FRACTION OF CF INPUT FUEL VALUE LOST DUE TO CARBON LOSSES		0.005	0.0405	0.0132	0.0038
	STACK TEMPERATURE	DEG F	540	150 (2)	450	335
	CF TEMPERATURE AT BOILER BOUNDARY	DEG F	70	70	70	72
	CF SPECIFIC HEAT	BTU/LB/DEG	0.5	0.3	0.3	0.3
	RDF TEMPERATURE AT BOILER BOUNDARY	DEG F	70	70	70	70
	AIR TEMP AT FR OR AIRHEATER INLET	DEG F	70	70	80	70
	PREHEATED COMBUSTION AIR TEMPERATURE	DEG F	70	70	370	70
	AVG ASH TEMPERATURE LEAVING BOILER BOUNDARY	DEG F	130	450	400	500
	COST OF ELECTRICITY	$/KWH	0.0535	0.0227	0.021	0.0281
*	CF (CONVENTIONAL FUEL) COST	$/LB	0.0274	0.039	0.0295	0.0281
*	DISPOSAL COST FOR SOLIDS (ash)	$/TON	0	16	15.19	4
	DAYS OF STORAGE DESIRED FOR RDF	DAYS	1	1	1	1
	LENGTH OF MECHANICAL TRANSFER CONVEYOR	MILES	0	0	0	0
	FINANCIAL LIFE OF PROJECT	YEARS	25	25	25	25
	Discount factor at 10%		9.54	9.54	9.54	9.54
	BASIC UNBURDENED OPERATOR WAGE RATE	$/HR	13.5	13.68	13.5	13.68
	AVAILABILITY OF EXISTING BOILER FIRED WITH CF, A FRAC. IF UNKNOWN, ENTER ZERO		0.95	0.98	0.9	0.99
	HYDROGEN MASS FRACTION OF AS RCVD CF		0.054	0.04	0.045	0.06
	APPLICABLE PARTICULATE EMISSIONS STANDARD	LB/MMBTU	0.32	0.11	0.23	0.11
	ANNUAL PRODUCTION OF MSW	TONS/YR	10000	42000	7540	5500
	BURDENING ON BASIC WAGE RATE, A MULTIPLIER		1.3	1.305	1.3	1.305
*	MSW TIPPING FEE	$/TON	3.4	10	7.58	9
	MSW TRANSPORTATION FEE	$/TON	6	6	6	6
*	MOISTURE ASH FREE HEATING VALUE, RDF	BTU/LB	9000	9000	9000	9000

Continued

TABLE 3-1. (continued)

(1)	Input Data	Units	Activity: Cherry Point	Puget Sound	Little Creek	Bangor
	IF THE FOLLOWING STATEMENTS ARE TRUE, ENTER 1					
	BOILER HAS SOOT BLOWERS FOR THE CONVECTIVE		1	1	1	1
	BOILER HAS SOOT BLOWERS FOR THE ECONOMIZER		1	1	1	1
	BOILER HAS AN ECONOMIZER		1	1	1	1
	ECONOMIZER, IF PRESENT, IS BARE TUBE		0	1	0	1
	BOILER HAS A HISTORY OF SLAGGING		0	0	0	0
	ADEQUATE BACKUP CAPABILITY EXISTS		1	1	1	1
	BOILER IS EQUIPPED WITH A BAGHOUSE		0	1	1	0
	BOILER IS EQUIPPED WITH AN ESP		1	0	0	1
	BOILER IS EQUIPPED WITH A VENTURI SCRUBBER		0	1	0	0
	BOILER HAS MULTICLONES OR CYCLONES		1	0	0	0
	BOILER WAS ORIGINALLY DESIGNED FOR COAL		1	1	1	1
	BOILER HAS MOVING OR DUMPING GRATE		1	1	1	1
	BOILER HAS AN ASH HANDLING SYSTEM		1	1	1	1
	THE CF ASSUMED CO-FIRED IS OIL		0	0	0	0
	THE CF ASSUMED CO-FIRED IS COAL		1	1	1	1
	THE CF ASSUMED CO-FIRED IS GAS		0	0	0	0
	THE FURNACE IS PC OR CYCLONE TYPE		0	0	0	0
	THE BOILER HAS AN ID FAN		1	1	1	1
	ALTERNATIVE SOLID FUEL IS NOT RDF BUT COAL		0	0	0	0
	ALTERNATIVE SOLID FUEL IS RDF-3		0	0	0	0
	ALTERNATIVE SOLID FUEL IS RDF-5 (d-RDF)		1	1	1	1
	ADDITIONAL INPUT REGARDING ORIGINAL BOILER DESIGN					
	FRACTIONAL MOISTURE OF AS RCVD DESIGN CF		0.1	0.1548	0.05	0.1
	FRACTIONAL ASH CONTENT OF AS RCVD DCF		0.1	0.0913	0.09	0.17
	FRACTIONAL EXCESS AIR REQD FOR DCF AT MCR		0.15	0.3	0.25	0.32
	TOTAL FUEL VALUE TO BOILER AT MCR NAMEPLATE WITH DCF	BTUH	1.1E+08	1.7E+08	1.1E+08	72000000
	HIGHER HEATING VALUE OF DCF	BTU/LB	14724	10290	13400	10700
	FRACTION OF HHVCFD LOST DUE TO CARBON LOSS		0.02	0.0405	0.0132	0.38
	DESIGN FUEL SPECIFIC HEAT	BTU/LB/DEG	0.3	0.3	0.3	0.3
	TEMPERATURE OF DCF AT BOILER BOUNDARY	DEG F	80	80	70	70
	HYDROGEN MASS FRACTION OF AS-RCVD CFD		0.0539	0.0405	0.06	0.061
	RADIATION LOSSES AS A FRACTION OF DTOTHHVCF		0.0053	0.0041	0.0053	0.0052
	ASH HANDLING SYSTEM CAPACITY	TPH	1.3	15	3	3.5
*	Average Seasonal Steam Demands					
	Summer	BTU	4.40E+07	4.22E+07	6.00E+07	1.51E+07
	Winter	BTU	2.00E+08	1.34E+08	1.50E+08	2.85E+07
	Spring/Fall	BTU	7.17E+07	8.81E+07	1.00E+08	2.52E+07

(1): Ranges evaluated in the sensitivity analysis
(2): For correct boiler efficiency calculation, boiler outlet temperature of 400 deg. F was used in the evaluation.

hazardous waste. When the sensitivity analysis results are compared between activities, it will be important to recognize how these factors vary among the activities. Table 3-2 summarizes these input variations.

TABLE 3-2. COMPARISON OF LOCAL ECONOMIC FACTORS THAT WILL IMPACT THE SIR

Variable	Units	Activity			
		Puget Sound	Sub Base Bangor	Little Creek	Cherry Point
Coal heating value	Btu/lb	10,500	12,300	13,800	14,724
Coal cost (delivered)	$/ton	$78.00	$56.20	$59.00	$54.80
Ash disposal cost	TPY	$16.00	$ 4.00	$15.19	$16.00
MSW generated	TPY	42,000	5,500	7,540	10,000
MSW disposal cost	$/ton	$16.00	$15.00	$13.58	$ 9.40

The Puget Sound activity has the lowest conventional fuel higher heating value (HHV) and the highest (delivered) coal price. Assuming the RDF is priced lower than the coal, the cost savings from substituting RDF for coal could be substantial.

Cherry Point and Bangor both report very low disposal costs for ash. Therefore, the additional ash disposal associated with burning RDF will have very little impact on these two activities. Conversely, Puget Sound and Little Creek report much higher ash disposal costs so the additional ash disposal costs from the RDF will have a more noticeable impact on the savings/investment ratio. Depending upon the specific regulations of each state, RDF ash may be determined to be a hazardous waste through the Extraction Procedure Toxicity test. Should this occur, the ash would have to be disposed of in a designated hazardous waste landfill, thus significantly increasing disposal costs. If an MSW disposal credit is possible, those activities that generate large volumes of MSW and currently have high disposal costs such, as Puget Sound, will benefit most significantly.

3.3 RANGE OF VALUES EVALUATED

Ten of the model input values can be controlled through either fuel specifications or boiler operation or can realistically be expected to vary over a reasonable range. These variables were utilized in the savings/investment ratio analysis to represent the possible operating/economic conditions. The variables were: (1) RDF moisture, (2) RDF ash, (3) RDF

moisture-ash-free higher heating value (MAF HHV), (4) co-fire ratio, (5) conventional fuel price, (6) RDF price, (7) MSW disposal cost, (8) ash disposal cost, (9) excess air, and (10) steam demand. Table 3-3 summarizes the values that were evaluated.

TABLE 3-3. INPUT DATA RANGES UTILIZED IN THE SENSITIVITY ANALYSIS

Model inputs	Values
RDF moisture	10, 20, 30 percent
RDF ash	10, 20, 30 percent
RDF cost	$2, equal to coal, 1/2 coal*
Excess air at MCR	Actual, +10 percent, -10 percent
Co-fire ratio	20, 40, 60 percent
Conventional fuel cost	Actual, +50 percent, +100 percent
Ash disposal cost	Actual, +50 percent, +100 percent
MSW disposal cost	Actual, +50 percent, +100 percent
RDF MAF HHV cost†	7000, 8000, 9000 Btu/lb
Steam demand	Actual, low season ×2, year-round at peak demand

*Equivalent to coal on a Btu per ton basis.
†Refuse-derived fuel, moisture-ash-free-higer heating value.

An explanation of the ranges that were evaluated and how those ranges were selected follows:

1., 2., and 3. The RDF percent moisture, percent ash, and MAF HHV: The levels selected for these factors were based on results from RDF co-fire test burns and other research evaluations (References 6, 7, 8, and 9). Moisture and ash were both evaluated at 10, 20, and 30 percent, while RDF MAF HHV was evaluated at 7000, 8000, and 9000 Btu/lb.

4. Co-fire ratio: The co-fire ratio represents the RDF fraction of the total higher heating value supplied to the boiler. The impact of this factor on the SIR was measured at co-fire ratios of 20, 40, and 60 percent. RDF has been successfully co-fired at these and higher ratios (References 6, 7, and 8).

5. Conventional fuel cost: A prime motivation in the past for evaluating the feasibility of co-firing RDFs has been the rising prices of conventional fossil fuels. Although the prices for these fuels are currently lower than they have been in the past, it is not unreasonable to expect that the prices will increase in the future. Therefore, the impact of conventional fuel prices on the SIR was measured at the current fuel prices (1986), at a 50 percent increase, and at a 100 percent increase. Such price increases are not unreasonable, as demonstrated by the coal price paid at the Sub Base, Bangor, Washington. In 1985, the contract price was $93.64/ton, delivered. The delivered price for 1986 is $43.80 (reference telecon, Appendix B).

6. RDF cost: RDF cost is expected to have the most significant impact on the SIR. To account for the typically lower heat content and higher ash content, the RDF must be priced below the current conventional fuel cost. EG&G (Reference 10) has conducted two economic evaluations of RDF-5 production costs. The first, based on vendor quotes for equipment, operation, and maintenance, resulted in an estimated RDF-5 price (including capital, operation, and maintenance) of $35 to $43/ton f.o.b. The second analysis utilized a computer model to evaluate the life cycle cost for an RDF-5 or RDF-3 facility. This analysis yielded a net processing cost per ton of approximately $20 to $40 for RDF-5 and $14 to $25 for RDF-3, depending on the specific type of operation. WETCO reports RDF-5 prices from $27 to $70/ton and RDF-3 prices of $4 to $18/ton (Reference 3). A relatively new RDF-5 production facility reports a price of $18/ton, delivered within a 50-mi radius of the Richmond, Virginia, plant (Reference Appendix B).

   Given this range of prices, it was determined that the effect on the SIR could be most effectively estimated by pricing the RDF as equivalent to the cost of the current conventional fuel on a Btu basis, half that cost, and essentially free with a nominal $2/ton delivery fee (as used in the baseline case, which is described in Section 3.1.). The $2/ton rate was chosen as a means of evaluating best case effects. If the SIR is not favorable at that level, further consideration would not be required because it is unlikely, based on the above references, that actual costs would be as favorable.

7. MSW disposal cost: MSW disposal cost will impact the SIR only if the Navy activity realizes a disposal savings by taking their waste to the RDF production facility at no tipping fee or at a tipping fee much less than the current fee. However, there will still be a cost associated with collecting the waste and transporting it to the production facility. Therefore, the entire disposal cost cannot be avoided. Furthermore, RDF production typically has a 50 percent fuel yield from MSW. This means that the remaining 50 percent will require standard disposal. Therefore, credit can only be assigned to 50 percent of the disposal fee. To account for this, the

sensitivity analysis considers both cases (with and without the disposal credit) at the following waste disposal rates: current, current plus 50 percent, current plus 100 percent.

8. Ash disposal cost: If RDF is co-fired with coal, the ash generation rate will increase due to the higher ash content of RDF compared to coal. Therefore, ash disposal costs will increase and impact the co-fire SIR by increasing the power plant facility maintenance costs. The effect of ash disposal costs was evaluated at the current rate, current plus 50 percent, and current plus 100 percent.

9. Steam demand: The evaluation of steam demand changes will help define at what steam demands the co-fire option becomes feasible. Although it is highly unlikely that the demands will change, a change or addition to a particular activity mission might require a change (increase) in steam demands. Should such a change occur, the co-fire option may be reconsidered in light of the increased demand. Current steam demands, current low season demand (doubled), and demand level at the reported peak were evaluated.

10. Excess air: The impact of excess air levels is interesting to note because excess air levels are not rigidly defined parameters and are often subject to operator control. Excess air levels may also have to be increased (based on RDF quality) in order to maintain stable co-fire combustion conditions.

SECTION 4.0
RESULTS

4.1 SIR: BASELINE AND SENSITIVITY ANALYSIS

To determine the optimum conditions for RDF co-firing, the model was exercised over a range of input values as discussed in the previous section. Summaries of the evaluated input variables and the resultant SIR for each Navy activity are presented in Table 4-1. The complete list of operational and economic outputs for each analysis can be found in Appendix E.

For the baseline case, actual conditions at Cherry Point, Bangor, and Little Creek yield savings/investment ratios of -0.19, -2.21, and -0.03, respectively. The SIR for Puget Sound was +2.18. Recall, however, that the baseline case assumes that RDF is essentially free. As the cost of RDF approaches one-half the cost of the conventional fuel (on a Btu basis), the SIR for Puget Sound drops to -4.5.

When an MSW disposal credit is considered for the baseline case, the savings/investment ratios become 0.04 for Cherry Point, -1.73 for Bangor, 0.35 for Little Creek, and 4.48 for Puget Sound. Puget Sound exhibits such a significant increase in the savings/investment ratio with the disposal credit because of the large volume of waste which can be credited (21,000 TPY) and their relatively high current disposal cost ($16/ton). MSW disposal cost would have to increase over 100 percent to yield a positive savings/investment ratio for Bangor at the current MSW generation rates.

As pointed out in Section 3.2, although the four Navy activities evaluated have technically similar boiler characteristics and operational requirements, there are local economic factors that give rise to varying degrees of response in the resultant SIR. Figures 4-1 through 4-10 illustrate the impact of these differences. Figure 4-1 is a graph of the resulting SIRs for each activity when the cost of RDF is essentially free, equal to one-half the current coal price (on a Btu basis), and equal to the coal price (including delivery). Due to the relatively high price paid for low quality coal at Puget Sound, the response of the SIR (as indicated by the slope) to changes in RDF prices is greater than that of the other facilities. The SIR for Puget Sound also responds more dramatically to changes in the RDF co-firing ratio as illustrated in Figure 4-2. This is once again primarily due to the relatively high cost of fuel at Puget Sound and indicates a favorable shift in the SIR as a result of displacing this expensive fuel with a less expensive RDF.

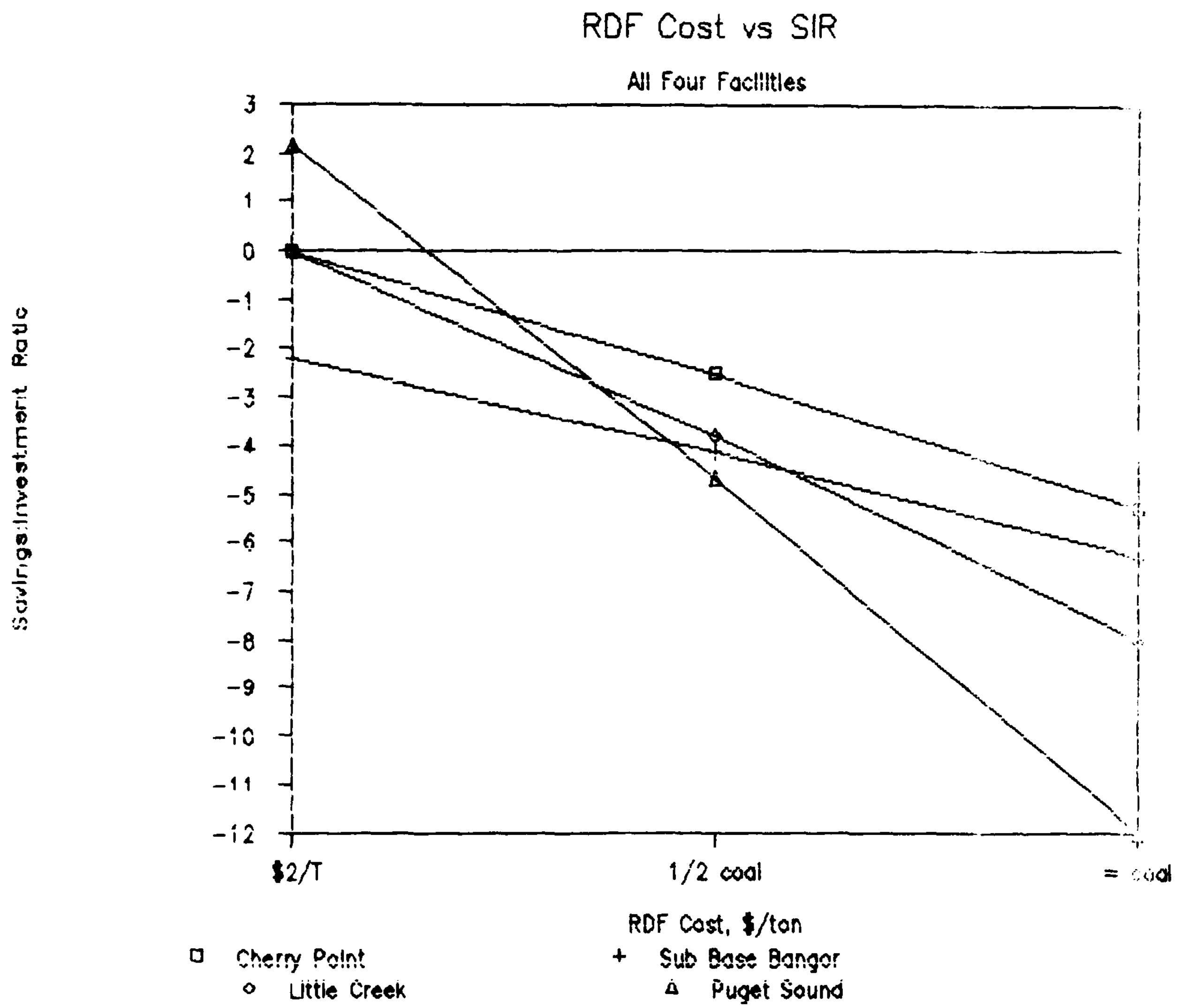
The significant effect due to MSW disposal cost at Puget Sound (as seen in Figure 4-3) is not only due to the high cost per ton for disposal but also reflects the impact of the comparatively large quantity of waste generated at this facility. Thus, it is the impact of the total cost for

TABLE 4-1. SIR VALUES OBTAINED AS A RESULT OF THE SENSITIVITY ANALYSIS

Input variable	Value	Cherry Point	Sub-base Bangor	Little Creek	Puget Sound
RDF percent moisture	10%	0.04	-2.12	0.27	2.01
	20%*	-0.19	-2.20	-0.03	2.18
	30%	-0.48	-2.33	-0.43	1.36
RDF percent ash	10%*	-0.19	-2.20	-0.03	2.18
	20%	-0.36	-2.33	-0.65	1.13
	30%	-0.54	-2.49	-1.49	0.30
RDF cost	$2*	-0.19	-2.20	-0.03	2.18
	= coal	-5.29	-6.30	-8.03	-11.21
	1/2 coal	-2.53	-4.15	-3.82	-4.54
Excess air	actual*	-0.19	-2.22	-0.03	2.18
	+10%	-0.27	-2.22	-0.19	1.75
	+20%	-0.36	-2.22	-0.35	1.75
Co-fire ratio	20%	-1.02	-2.27	-0.92	-0.06
	40%*	-0.19	-2.20	-0.03	2.18
	60%	0.79	-1.77	1.05	4.04
Conventional fuel cost	Actual*	-0.19	-2.20	-0.03	2.18
	+50%	1.50	-1.49	1.81	5.41
	+100	3.18	-0.78	3.65	8.63
Ash disposal cost†	Actual*	-0.19	-2.20	-0.03	2.18
	+50%	-1.12	-2.32	-0.60	1.08
	+100%	-1.49	-2.43	-1.18	0.42
MSW cost with disposal credit	Actual*	0.04	-1.73	0.35	4.00
	+50%	0.36	-1.32	0.69	5.82
	+100%	0.67	-0.92	1.03	7.63
RDF HHV	7000	-0.63	-2.38	-0.62	1.19
	8000	-0.38	-2.28	-0.29	1.49
	9000*	-0.19	-2.20	-0.03	2.18
Steam demand	Actual	-0.19	-2.20	-0.03	2.18
	Low x2	0.38	-1.77	0.34	2.93
	Peak	0.55	-1.62	0.34	6.26
Baseline SIR without disposal credit		-0.19	-2.21	-0.03	2.18
Baseline SIR with disposal credit		0.04	-1.73	0.35	4.48

*Value used in the baseline case.

†Cherry Point reported $0/ton for ash disposal. Analysis based on cost equal to MSW disposal and MSW disposal plus 50 percent.



RDF Cost per Ton, Delivered

	$2/T	1/2 coal	= coal
Cherry Point	$2.00	$15.00	$30.31
Bangor	$2.00	$20.60	$41.20
Little Creek	$2.00	$19.24	$38.47
Puget Sound	$2.00	$33.43	$66.86

Figure 4-1. Impact of RDF cost on the SIR for all four activities.

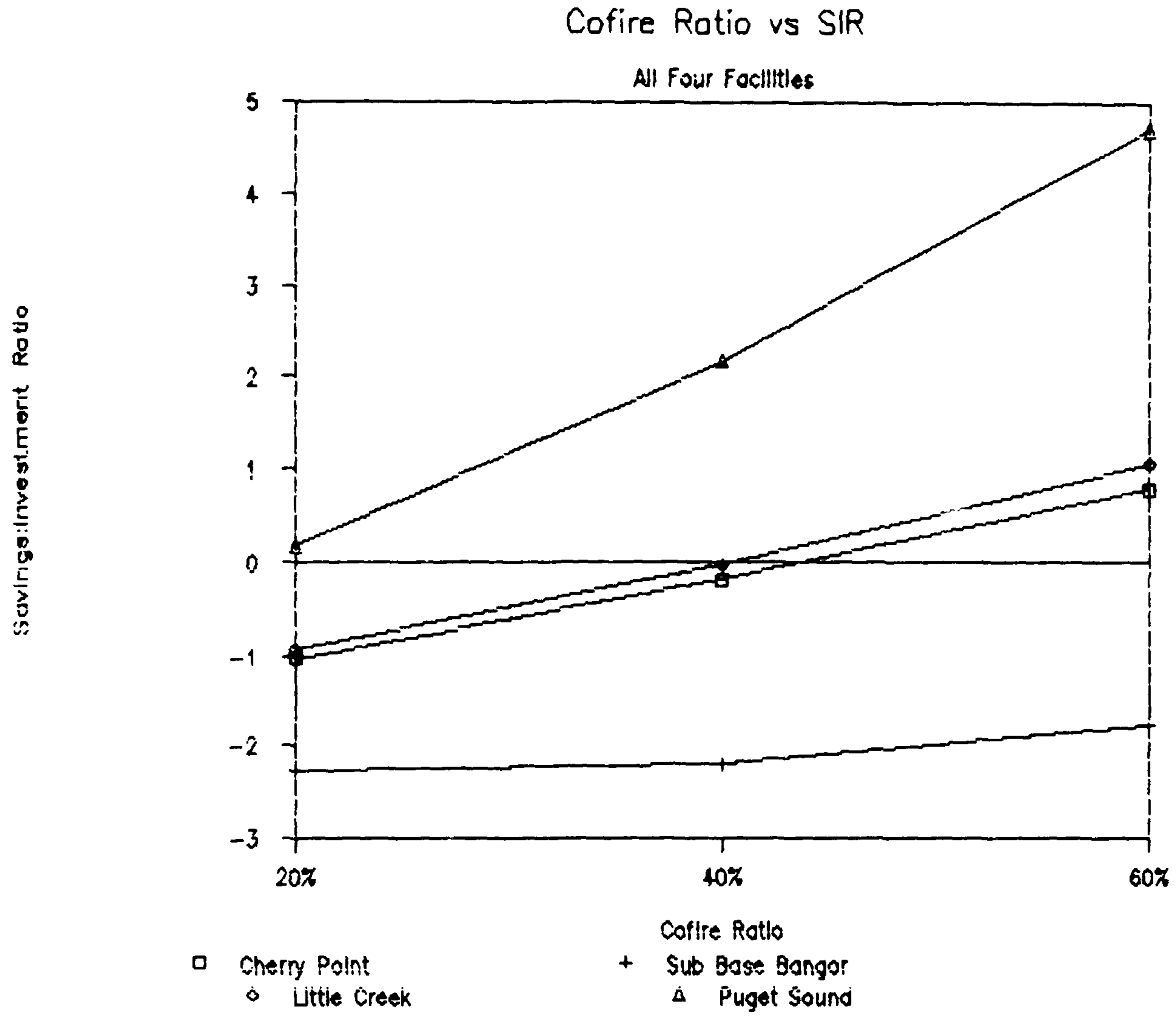
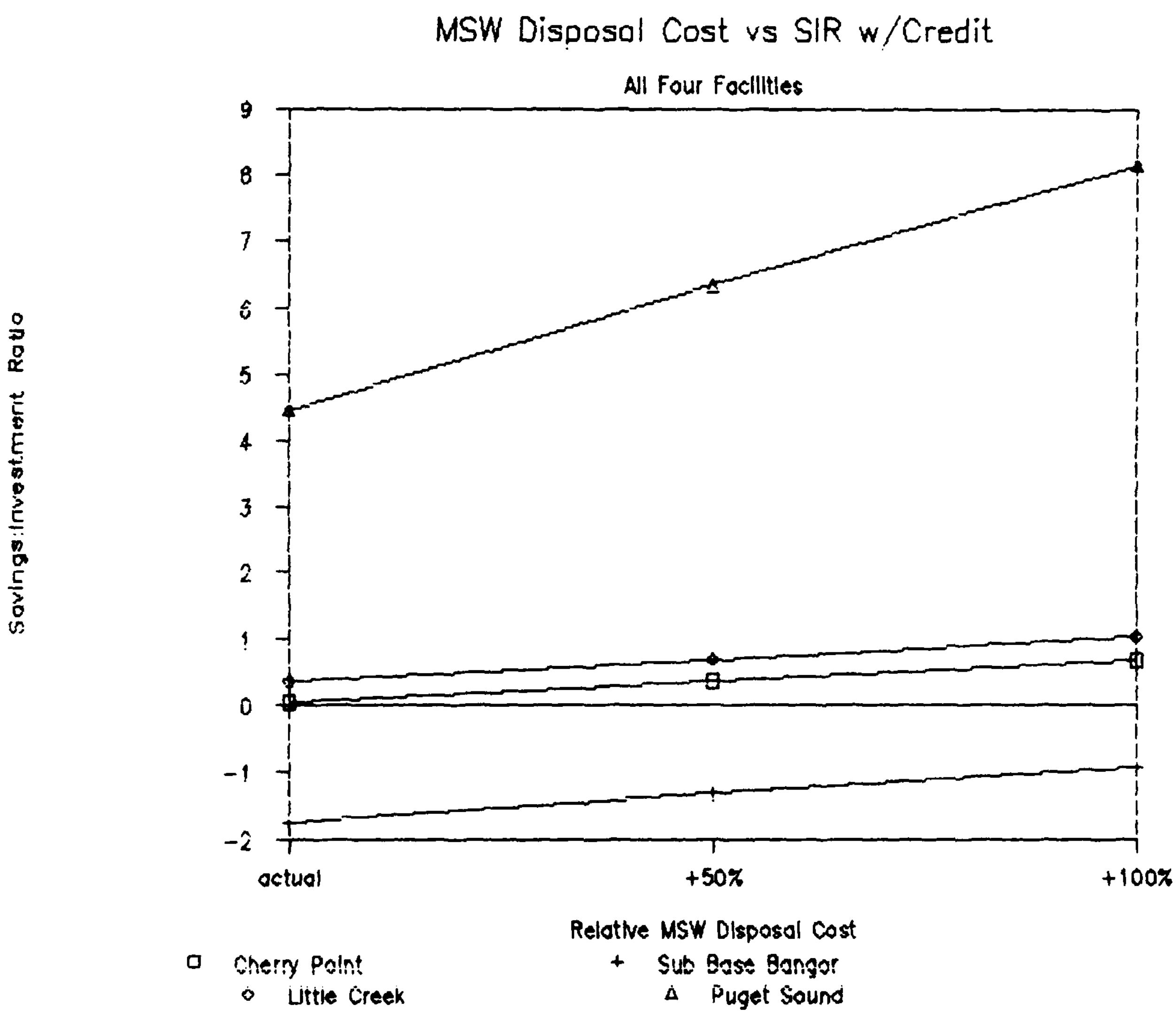
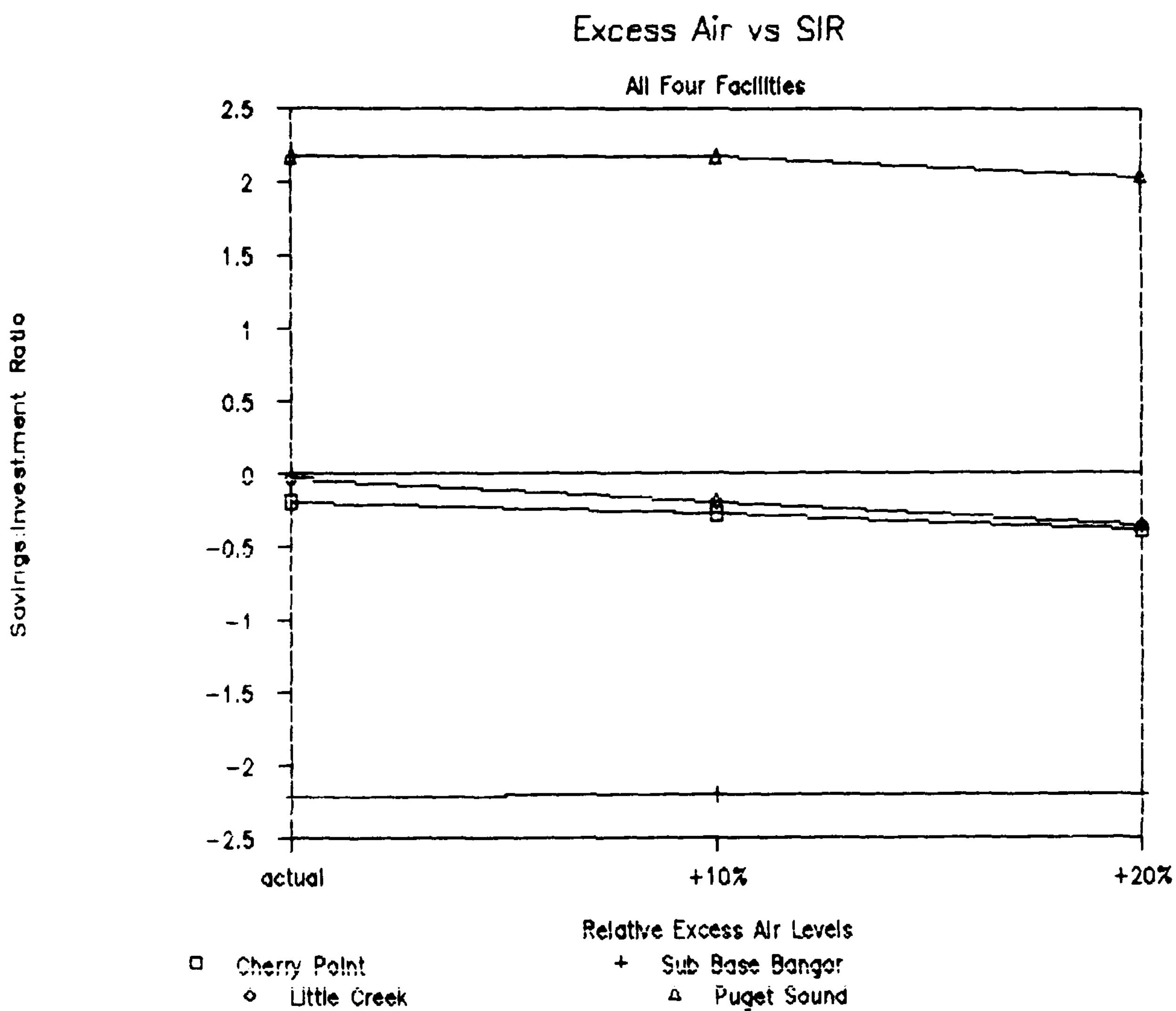


Figure 4-2. Impact of the co-fire ratio on the SIR for all four activities.



MSW Disposal Credit @ Various Disposal Rates	actual	+50%	+100%
Cherry Point	$9.40	$14.10	$18.80
Bangor	$15.00	$22.50	$30.00
Little Creek	$13.58	$20.37	$27.16
Puget Sound	$16.00	$24.00	$32.00

Figure 4-3. Impact of MSW disposal cost on the SIR for all four activities.



Excess Air: Values

	actual	+10%	+20%
Cherry Point	**0.17**	**0.27**	**0.37**
Bangor	**0.22**	**0.32**	**0.42**
Little Creek	**0.33**	**0.43**	**0.53**
Puget Sound	**0.30**	**0.40**	**0.50**

Figure 4-4. Impact of excess air levels on the SIR for all four activities.

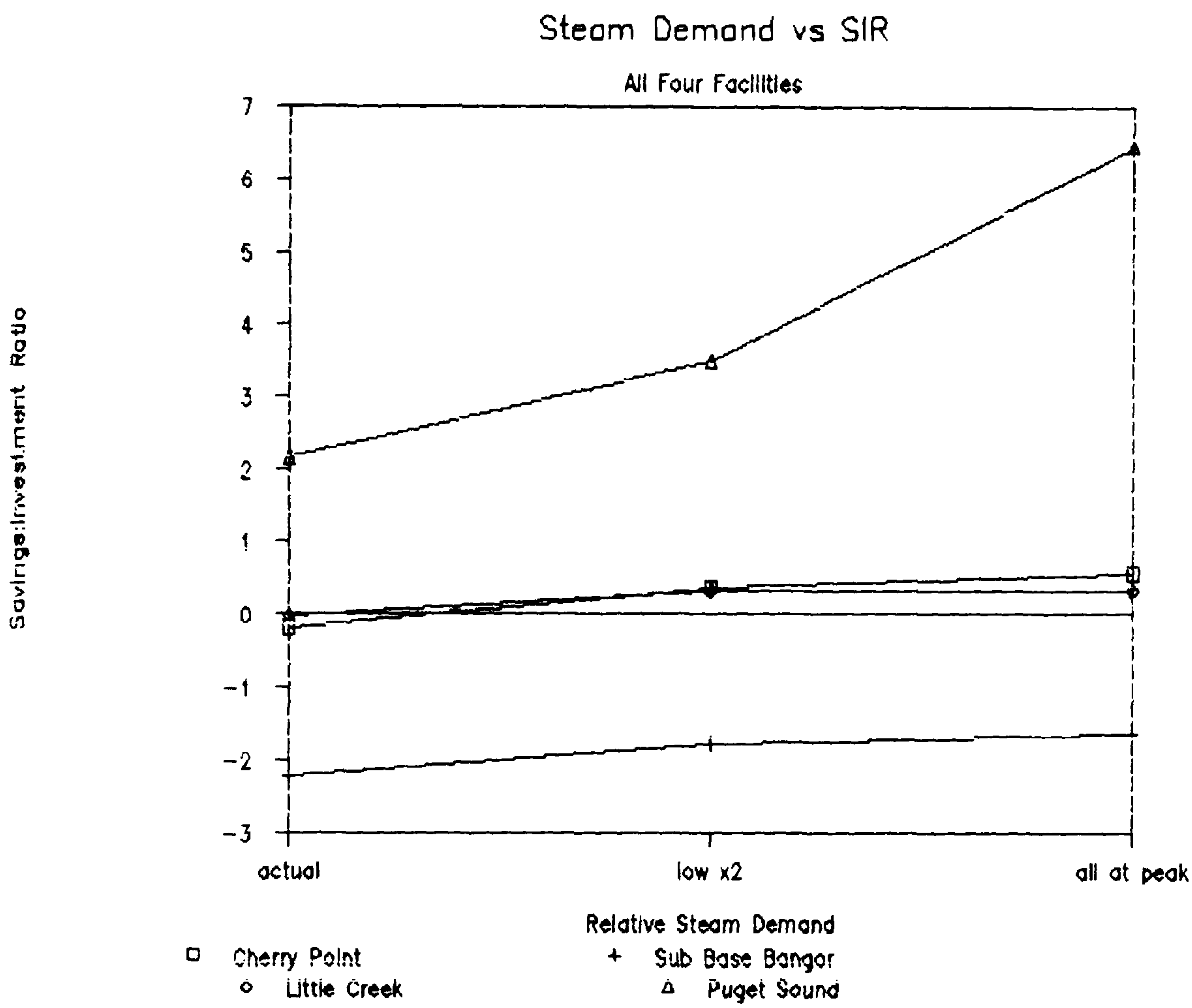


Figure 4-5. Impact of the steam demand on the SIR for all four activities.

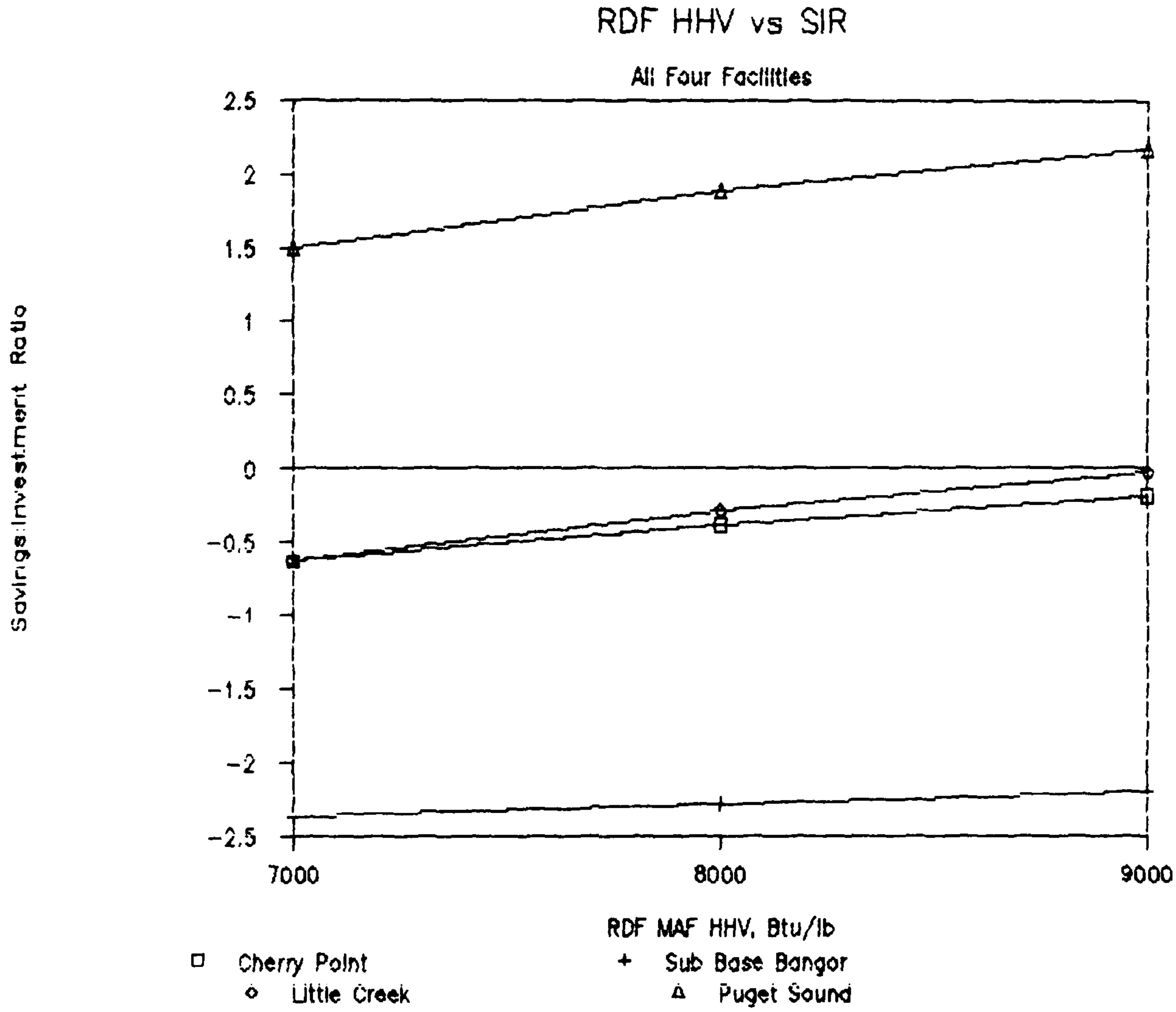


Figure 4-6. Impact of the RDF HHV on the SIR for all four activities.

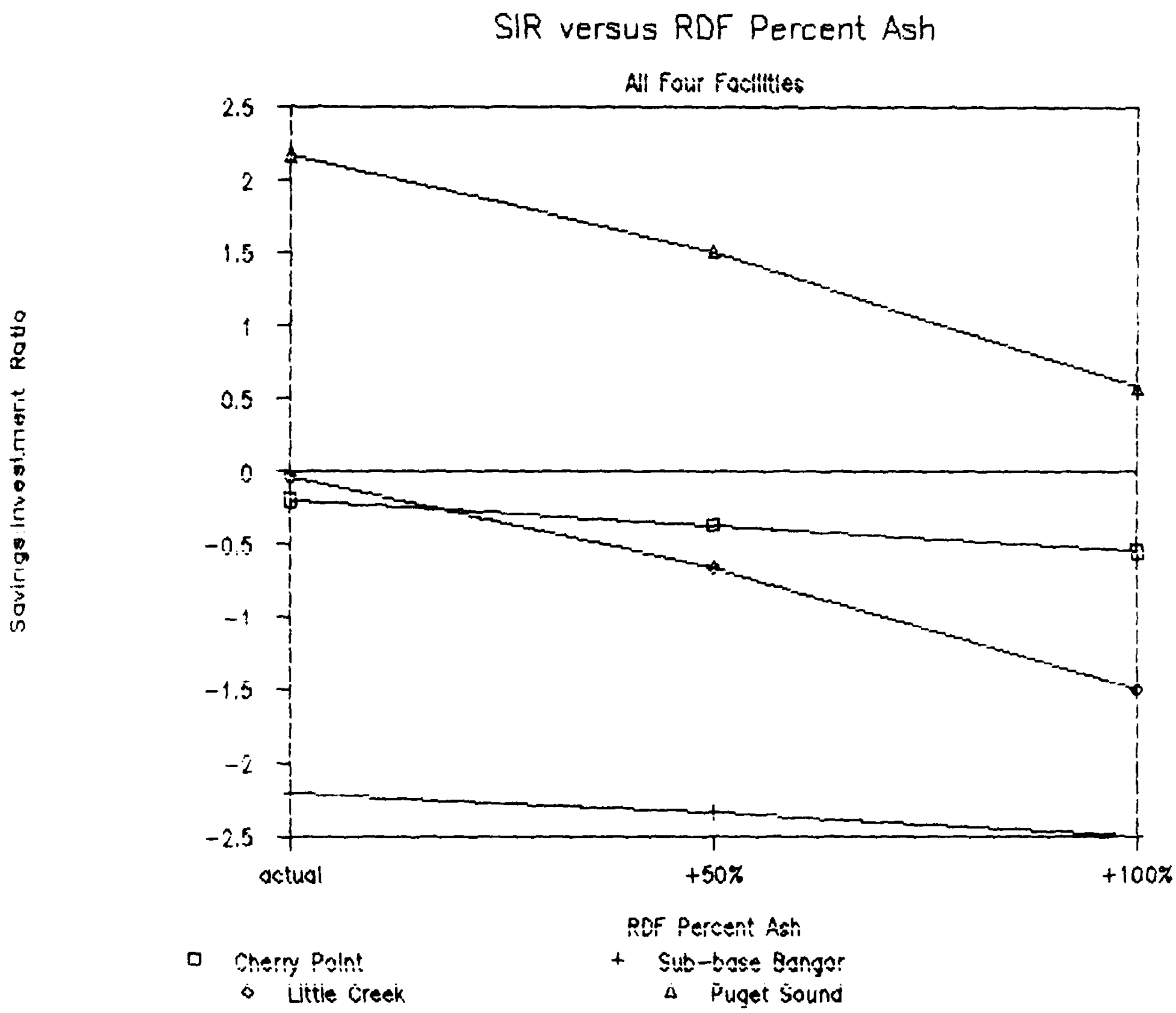


Figure 4-7. Impact of RDF percent ash on the SIR for all four activities.

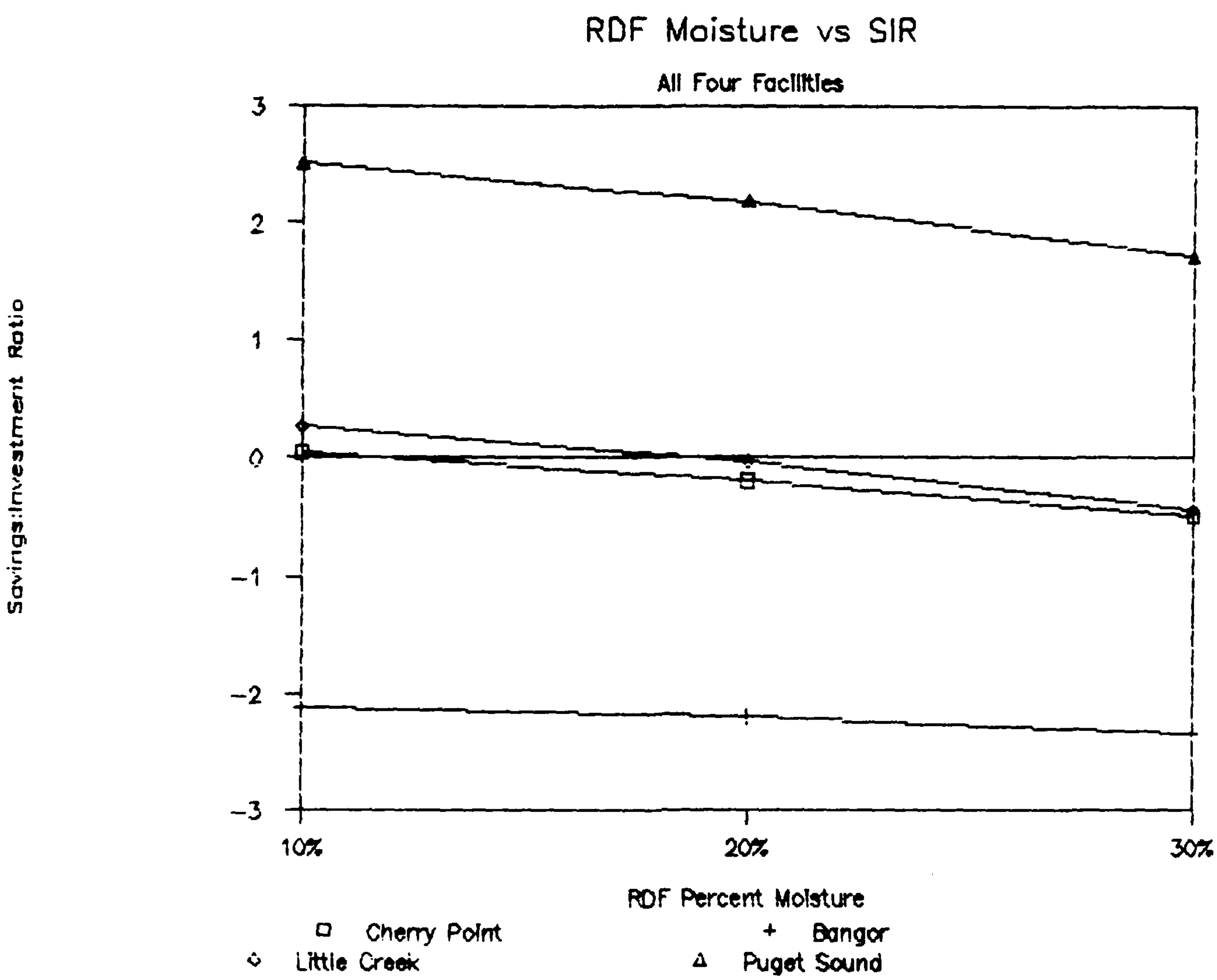
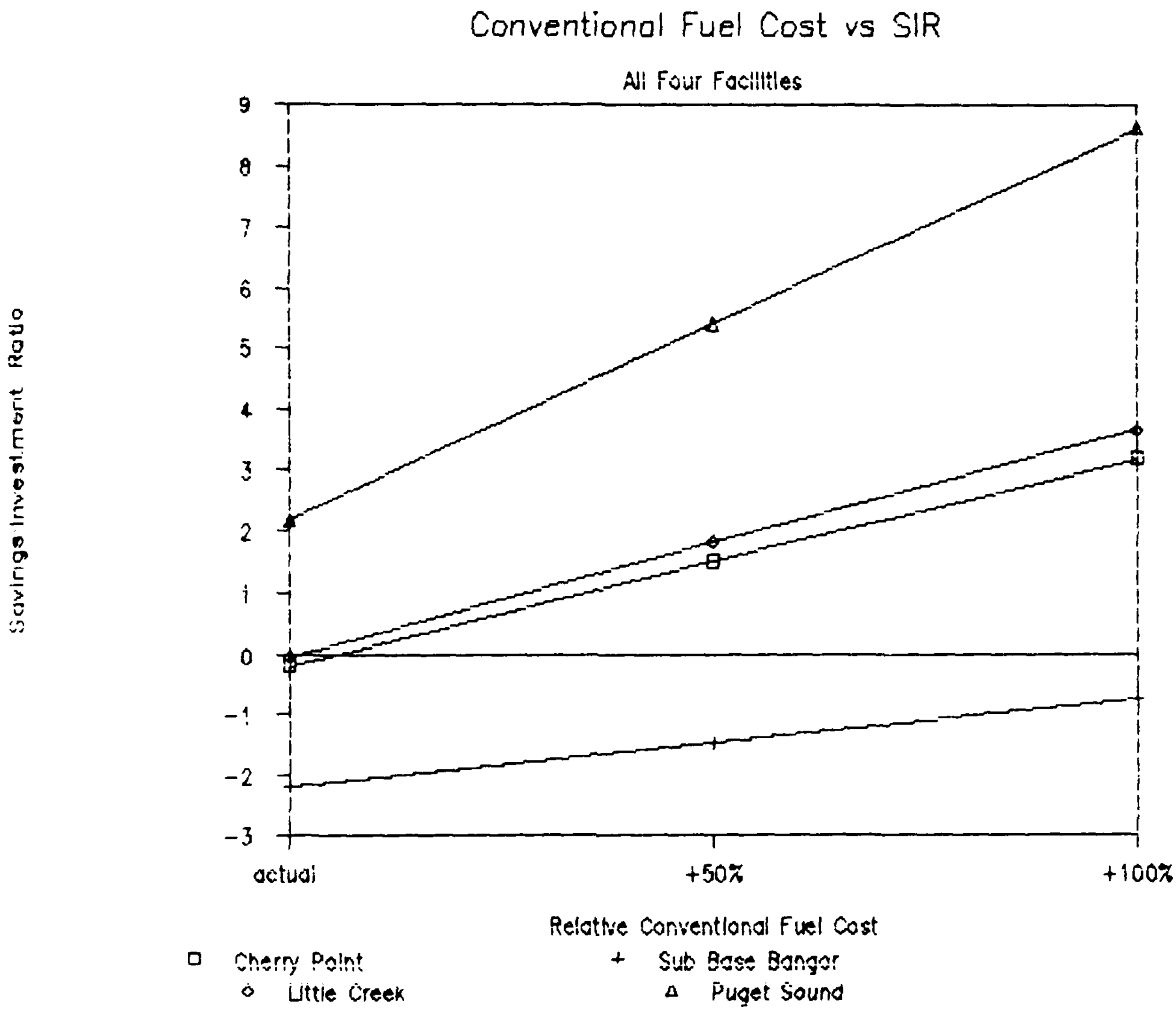
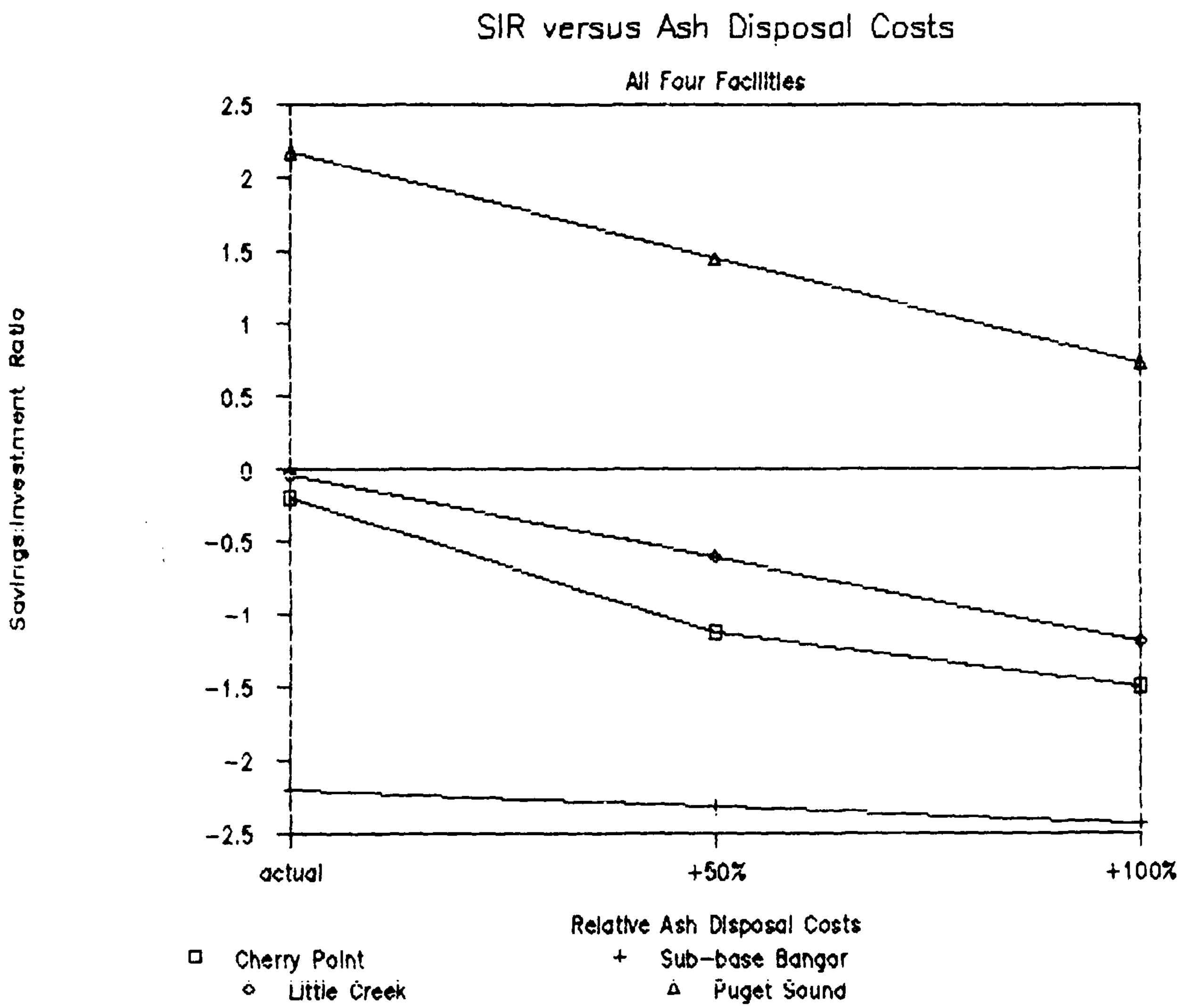


Figure 4-8. Impact of RDF percent moisture on the SIR for all four activities.



Conventional Fuel Cost Values	actual	+50%	+100%
Cherry Point	$54.80	$82.20	$109.60
Bangor	$56.20	$84.30	$112.40
Little Creek	$59.00	$88.50	$118.00
Puget Sound	$78.00	$39.00	$117.00

Figure 4-9. Impact of the conventional fuel cost on the SIR for all four activities.



Ash Disposal Cost: Rates	actual	+50%	+100%
Cherry Point	$0.00	$9.40	$14.80
Bangor	$4.00	$6.00	$8.00
Little Creek	$15.19	$22.79	$30.38
Puget Sound	$16.00	$24.00	$32.00

Figure 4-10. Impact of ash disposal costs on the SIR for all four activities.

waste disposal that is reflected in this figure. Other figures in this group have plots with similar slopes indicating that the responses of the SIR to the various parameters are similar for all facilities.

Another way of looking at the sensitivity of the SIR to changes in various parameters is to look at the range of the response of the SIR. This range is illustrated graphically for each parameter, at each activity, in Figures 4-11 through 4-14. It is apparent that changes in the cost of RDF and current fuel produce the widest range of response in the SIR. For three of the four activities, the RDF substitution rate (co-fire ratio) has the next highest impact and reemphasizes the importance of the fuel costs. In general, the site specific factors of steam demand and ash and MSW disposal costs have the next highest impacts, with RDF characteristics having the least impact. Of the RDF characteristics, ash content had the greatest impact in three out of four cases and moisture content and heating value had nearly identical impacts. Puget Sound is more sensitive to the effects of ash content due to its higher ash disposal cost.

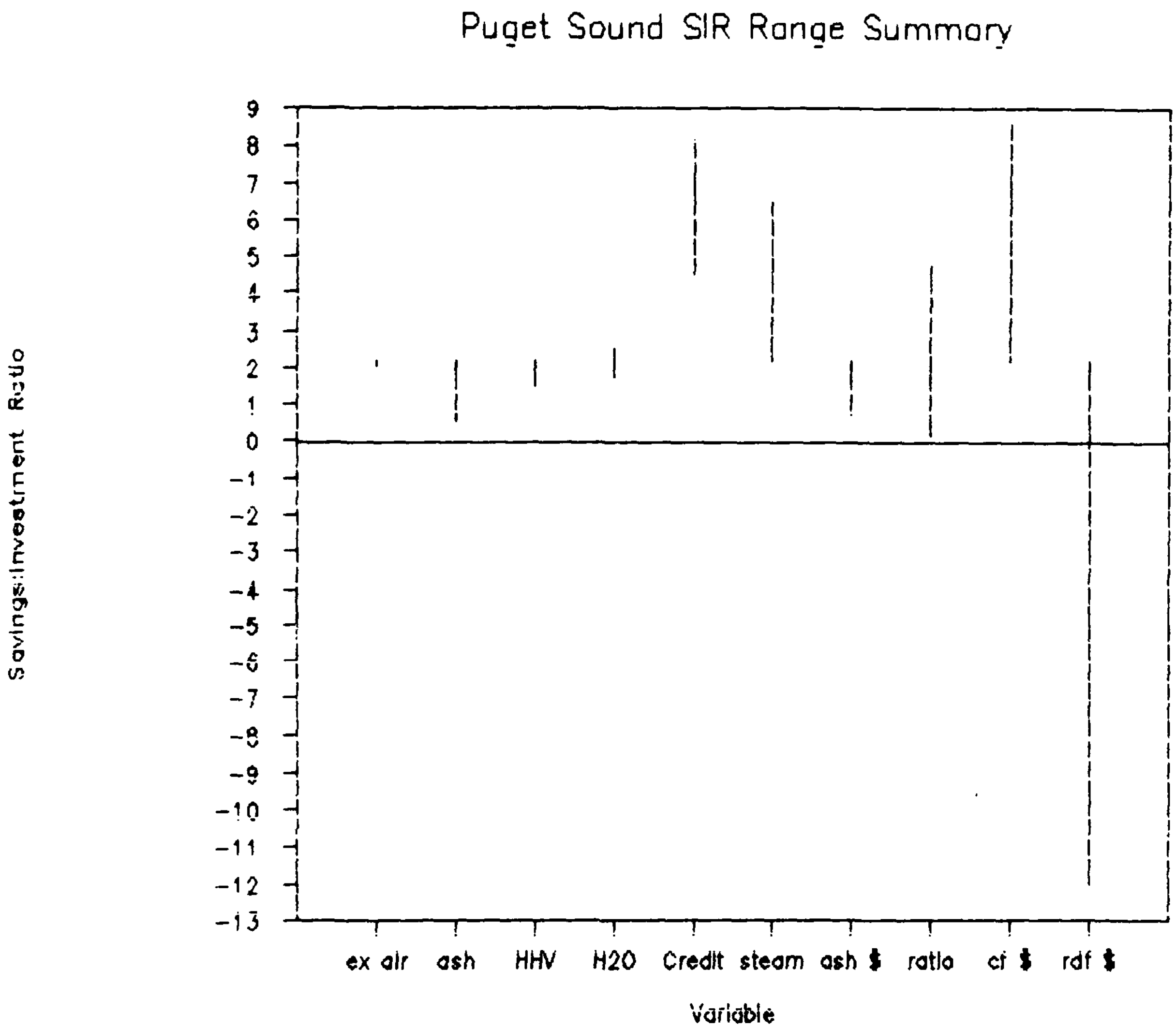
As RDF costs approach typical market prices (see previous section for values), the savings/investment ratio makes significant jumps towards the negative side. The Puget Sound SIR goes from a baseline of 2.18 to -12 as RDF cost goes from $2/ton (delivery cost only) to $67/ton. The other facilities exhibit the same reaction to a lesser degree.

As conventional fuel costs rise, the SIR obviously improves. The higher cost results in a higher savings in avoided conventional fuel costs. With the exception of Sub Base Bangor, the SIR is positive as the CF price approaches and exceeds a 50 percent increase.

Steam demand affects the SIR because this is the factor which determines when co-firing is possible. If the steam demand is low, relative to the co-fire turndown rating, the model does not assign credit for co-firing. If the steam demand meets or exceeds the co-fire MCR, then the model assigns 100 percent co-firing capability. Therefore, if cofiring is possible 100 percent of the time, the avoided conventional fuel cost is maximized. However, the economic benefits of the CF avoided costs are dramatically reduced as RDF price approaches the cost of the CF.

4.2 BEST CASE EVALUATION

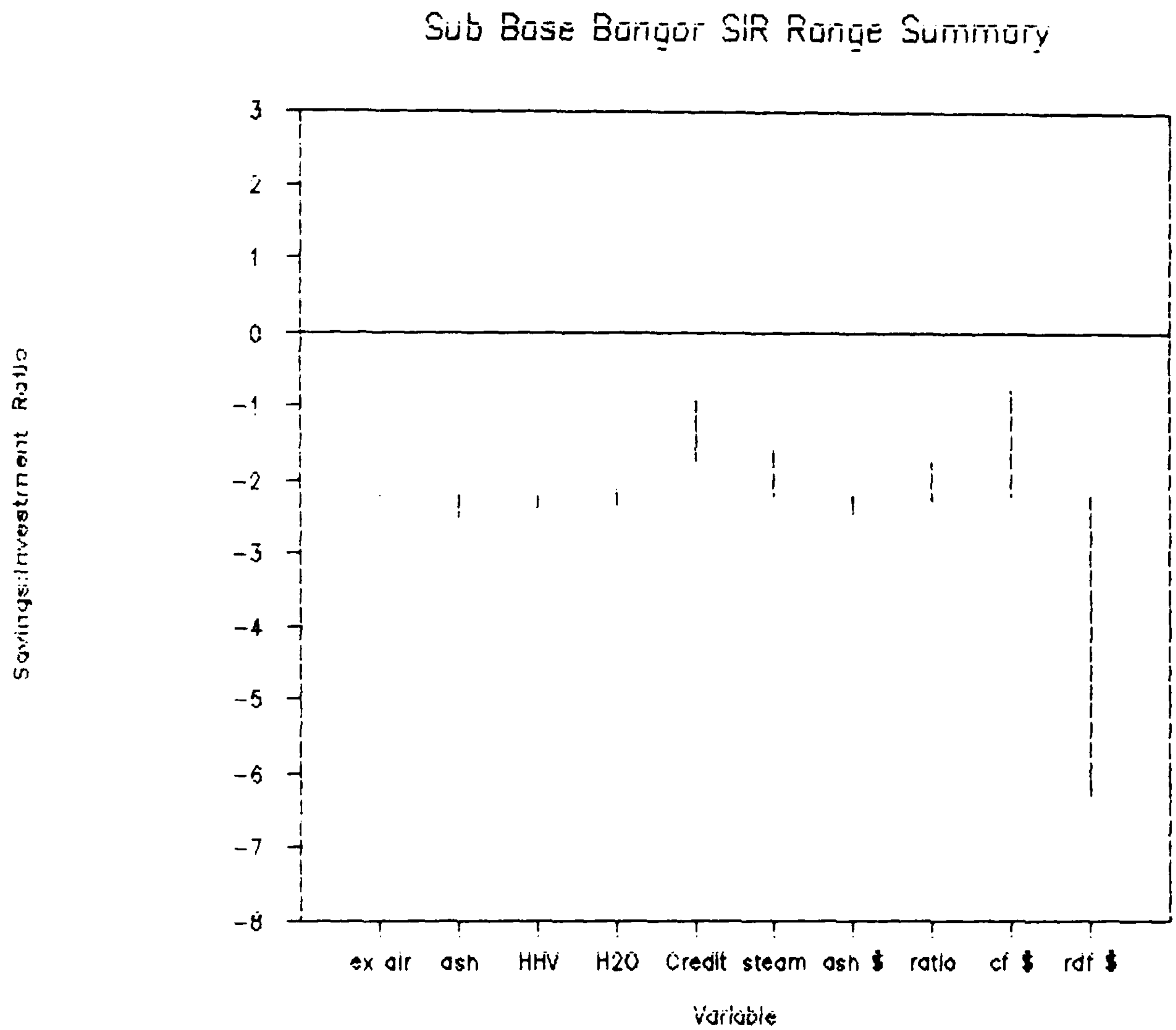
The RDF Cost Model represents a mechanism for evaluating RDF co-firing feasibility at the most preliminary stage. As such, all conditions relating to the specifics of co-firing, including RDF cost, must be based on assumptions. Therefore, an "actual" case is not possible. The cases presented here are intended to represent optimistic assumptions. If, under these optimistic conditions, the model predicts an unacceptable SIR, co-firing will most certainly not be feasible under "actual" conditions, and further investigation would not be required. If the SIR is favorable, a more detailed analysis may be warranted.



Key:

Ex air: percent excess air
ash : RDF percent ash
HHV : RDF heating value, MAF
H2O : RDF percent moisture
Credit: MSW disposal credit
steam : steam demand
ash $: ash disposal cost
ratio : cofire ratio
cf $: conventional fuel cost
RDF $: RDF cost

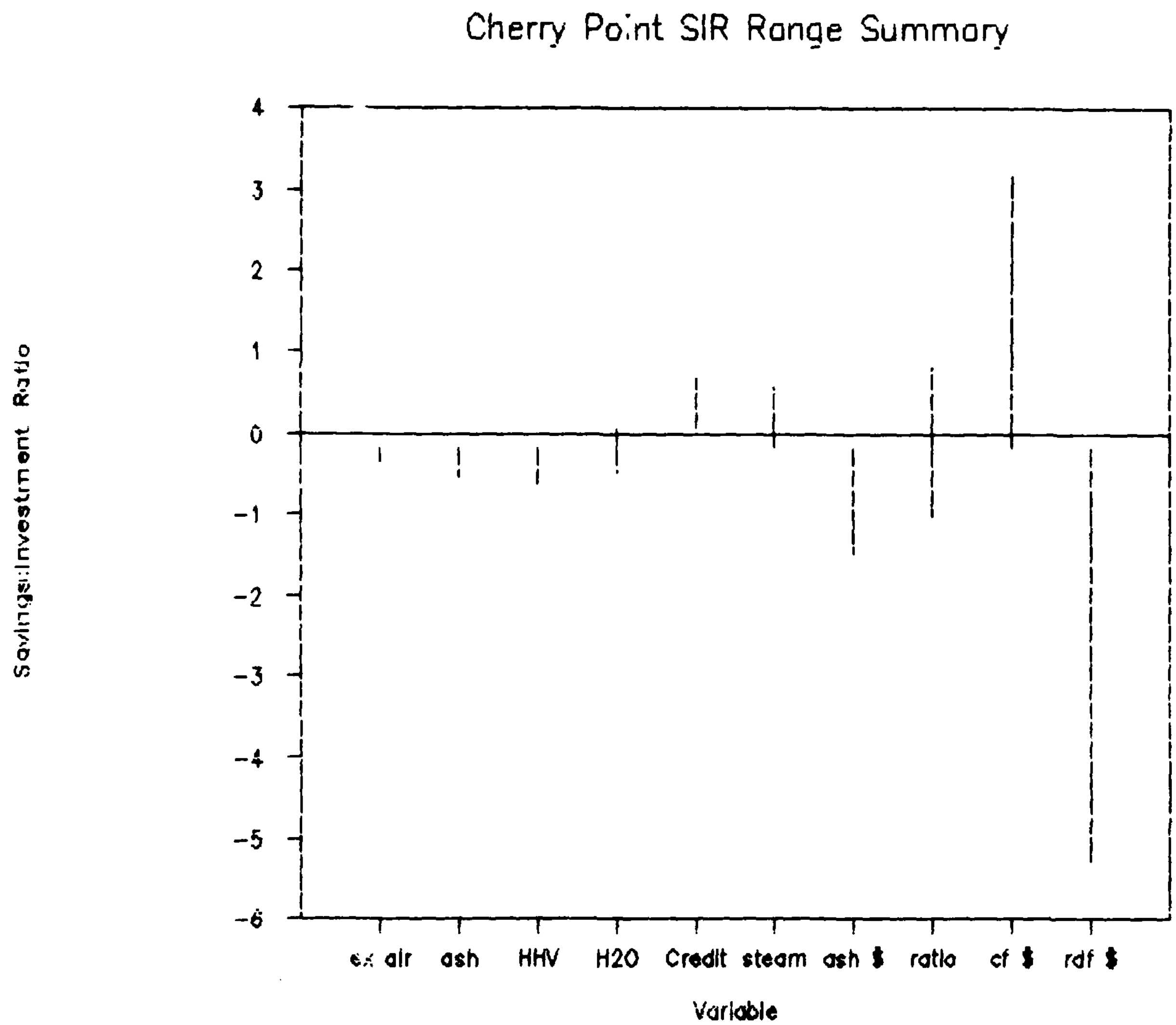
Figure 4-11. Range of SIR values obtained for Puget Sound from the Sensitivity Analysis.



Key:

Ex air: percent excess air
ash : RDF percent ash
HHV : RDF heating value, MAF
H2O : RDF percent moisture
Credit: MSW disposal credit
steam : steam demand
ash $: ash disposal cost
ratio : cofire ratio
cf $: conventional fuel cost
RDF $: RDF cost

Figure 4-12. Range of SIR values obtained for Sub Base Bangor from the Sensitivity Analysis.



Key:

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Ex air: percent excess air
ash   : RDF percent ash
HHV   : RDF heating value, MAF
H2O   : RDF percent moisture
Credit: MSW disposal credit
steam : steam demand
ash $ : ash disposal cost
ratio : cofire ratio
cf $  : conventional fuel cost
RDF $ : RDF cost
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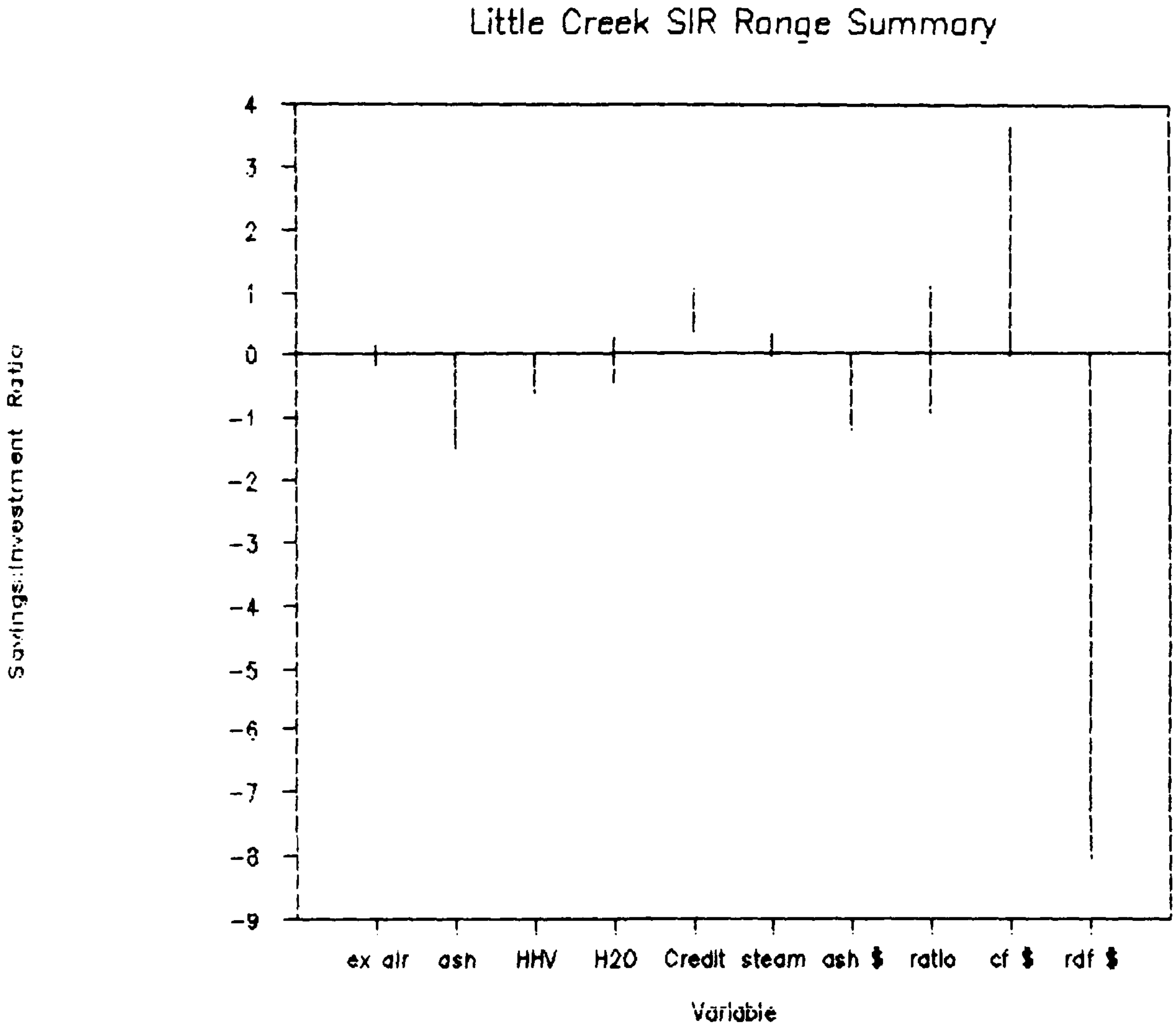
Figure 4-13. Range of values obtained for Cherry Point from the Sensitivity Analysis.



Key:

Ex air: percent excess air
ash : RDF percent ash
HHV : RDF heating value, MAF
H2O : RDF percent moisture
Credit: MSW disposal credit
steam : steam demand
ash $: ash disposal cost
ratio : cofire ratio
cf $: conventional fuel cost
RDF $: RDF cost

Figure 4-14. Range of values obtained for Little Creek from the Sensitivity Analysis.

In all cases, the optimum economic scenario is achieved when RDF cost, moisture, percent ash, ash disposal cost, and excess air are minimized; and conventional fuel cost, steam demand, RDF HHV, co-fire ratio, and MSW disposal cost are maximized.

Even though the range of values evaluated in the best case analysis are all theoretically possible, the probability of all of them attaining their optimum values at the same time is extremely remote. The analysis of this best possible case does, however, put the economic feasibility of the various activities into perspective. Table 4-2 presents the results of this best case analysis along with the results of a more probable "Best Fuel Cost Ratio" case and the baseline case with disposal credits for MSW. The more probable "Best Fuel Cost Ratio" case assumes the use of highest quality RDF at a price equal to one-half the current price of coal (Btu basis), the co-fire ratio is at 60 percent, the price of coal remains at the current price, the MSW disposal cost doubles, the excess air, steam demand, and ash disposal costs are at current values.

TABLE 4-2. BEST CASE SIR ANALYSIS RESULTS

	Puget Sound	Cherry Point	Little Creek	Sub Base Bangor
Best possible:				
SIR	34.4	9.7	10.4	4.2
RDF cost ($/ton)	2	2	2	2
Conventional fuel ($/ton)	156	109.6	118	112.4
RDF moisture (percent)	10	10	10	10
RDF ash (percent)	10	10	10	10
Co-fire ratio (percent)	60	60	60	60
Excess air (percent)	30	17	23	32
Ash disposal cost ($/ton)	16	0	15.19	4
MSW disposal cost ($/ton)	32	18.8	27.16	30
RDF MAF HHV (Btu/lb)	9000	9000	9000	9000
Steam demand	Peak	Peak	Low × 2	Peak
Best fuel cost ratio:				
SIR	1.7	-2.5	-2.4	-3.1
RDF cost ($/ton)	33.43	15	19.24	20.6
Conventional fuel ($/ton)	78	54.8	59	56.2
RDF moisture (percent)	10	10	10	10
RDF ash (percent)	10	10	10	10
Co-fire ratio (percent)	60	60	60	60
Excess air (percent)	30	17	33	32
Ash disposal cost ($/ton)	16	9.4	15.19	4
MSW disposal cost ($/ton)	32	18.8	27.16	15
RDF MAF HHV (Btu/lb)	9000	9000	9000	9000
Steam demand	Actual	Actual	Actual	Actual
Baseline:				
SIR	4.5	0	0.4	-1.7
RDF cost ($/ton)	2	2	2	2
Conventional fuel ($/ton)	78	54.8	59	56.2
RDF moisture (percent)	20	20	20	20
RDF ash (percent)	10	10	10	10
Co-fire ratio (percent)	40	40	40	40
Excess air (percent)	30	17	33	32
Ash disposal cost ($/ton)	16	0	15.19	4
MSW disposal cost ($/ton)	16	9.4	13.58	15
RDF MAF HHV (Btu/lb)	9000	9000	9000	9000
Steam demand	Actual	Actual	Actual	Actual

SECTION 5.0
SUMMARY
CONCLUSIONS AND RECOMMENDATIONS

5.1 PROGRAM SUMMARY

The objective of this project was to determine the cost effectiveness of co-firing RDF in existing Navy boilers using the NCEL RDF Cost Model and site specific boiler and cost data. The four Naval activities listed below were selected on the basis of boiler type and condition as being the most technically suited Naval shore facilities for co-firing RDF.

- Marine Corp Air Station, Cherry Point, North Carolina
- Naval Submarine Base Bangor, Bremerton, Washington
- Puget Sound Naval Shipyard, Bremerton, Washington
- Naval Amphibious Base Little Creek, Norfolk, Virginia

Prior to performing the analysis, the model was carefully reviewed for errors, omissions, and appropriateness to the candidate sites. Twelve modifications were made to the model. Input variables were evaluated over a reasonable range to determine the sensitivity of the model to these changes. Cost effectiveness was measured by the SIR, which was computed over a range of cost and operating conditions to establish realistic and optimum RDF co-firing scenarios for each facility.

5.2 CONCLUSION REGARDING CO-FIRING FEASIBILITY

Of the four activities, Puget Sound was determined to have the highest probability for co-firing RDF in a cost-effective manner. The SIRs for the other three activities were at or below zero for all but the most optimistic conditions. There are two site specific factors that give Puget Sound a co-firing advantage over the other activities. Puget Sound is currently paying a higher price for poorer quality coal than any other activity analyzed, and they are paying a higher price for disposal of a larger quantity of solid waste than the others. These current economic disadvantages combine to give Puget Sound the highest potential for cost savings through RDF co-firing (assuming the MSW disposal credit is possible). SIR projections for Puget Sound under the baseline conditions, which assumes free RDF at $2/ton (for delivery only) and a MSW disposal credit, yields a 4.5 SIR. If a reasonable price is assigned to RDF and optimum but realistic assumptions are made regarding other site specific economic factors, the model projects a 1.7 SIR. To obtain a break even SIR (1.0) under current operating and economic conditions, the delivered RDF price would have to be $18.20/ton if a MSW disposal credit was possible, or $7.50/ton if the MSW disposal credit was not possible. Based on past and projected RDF prices, such rates are not attainable. Therefore, co-firing at the present time is not economically

feasible. As illustrated by the sensitivity analysis, coal and MSW disposal prices would have to double (in terms of current dollars) before co-firing could be considered on an economic basis.

5.3 CONCLUSIONS REGARDING THE SENSITIVITY ANALYSIS

Ten model inputs were identified as potentially having the most significant impact on the economic projections of the model. These inputs were varied, one at a time, over a realistic range of values, to determine their individual impact. This one-at-a-time evaluation helps to establish the relative order of magnitude of each effect; but, due to the highly interactive nature of the model inputs, it is not possible to develop an absolute ranking. The inputs are discussed below in groups reflecting their relative order of impact and their interactions.

5.3.1 Cost of RDF and Conventional Fuel and Co-Fire Ratio

The SIR is maximized when the cost differential between coal and RDF is at its greatest. In this situation, the displacement of coal by RDF has the most economic advantage and considerable cost savings can be realized. This can be further enhanced by increasing the co-firing substitution ratio to whatever extent possible (100 percent RDF combustion has been successfully demonstrated in several test burns, References 6, 7, and 8). As RDF becomes more expensive or as coal prices are depressed, the economic advantage diminishes and the SIR is significantly lowered. As the cost differential between fuels decreases, the advantage of higher substitution rates also diminishes. If fuel prices are equal on a Btu basis, there are no cost savings, and a negative SIR results because of the added capital cost of RDF firing.

5.3.2 Steam Demand

THe SIR is maximized when the steam demand of the facility is within the achievable co-fire steam supply range. When the demand is outside the achievable supply, the ability to substitute RDF for conventional fuel is restricted and the avoided conventional fuel costs are therefore reduced. Any changes in total steam demand, due to changes in activity mission, could significantly alter the SIR.

Although it is not generally possible to control total steam demand, co-firing can be optimized when multiple boilers are required to meet the current demand. One boiler can be designated as the primary co-firing boiler and operated under optimum co-firing conditions, while the other boiler(s) provide the balance of the steam demand with conventional fuel or with restricted co-firing. The operational flexibility presented by multiple boilers has considerable impact on the time when effective RDF co-firing is possible and, thus, the SIR. Operational flexibility was not addressed by the RDF Cost Model but should be fully explored if future detailed analyses are undertaken.

5.3.3 Cost of Ash and MSW Disposal

Depending upon local conditions, either the cost of ash disposal or the avoided cost of MSW disposal can have a greater impact on the SIR. For Puget Sound, MSW disposal credits dominate because of the large quantity (21,000 TPY) of waste at a relatively high tipping fee ($16/ton). The ability to negotiate a cost reduction for disposal of Puget Sound base solid waste (via a disposal credit) would have a significant positive impact, raising the baseline SIR from 2.2 to 4.5. If the tipping fee were to double, which is not inconceivable (Reference 12), the baseline SIR would increase to 8.2. The composition of base solid waste was not addressed by the model other than to assume that 50 percent could be converted into RDF; therefore, avoiding one-half of the disposal cost. If significant portions of the total solid waste are not suitable for RDF production or are noncombustible in nature, extra consideration should be given to the impact of composition on the solid waste disposal credit.

The reported costs for ash disposal ranged from no cost at Cherry Point to $16/ton at Puget Sound. Depending on RDF ash content, co-fire ratio, and total RDF utilized, the quantity of ash can also vary considerably. Significant increases in RDF ash disposal costs are even more probable than increases in MSW disposal costs. Various state environmental departments may find RDF ash to be a hazardous waste because of results of the Extraction Procedure Toxicity (EP Tox) test and various local testing procedures. Such a finding would require that all ash resulting from co-firing be disposed of in a specially designated hazardous waste landfill. The resulting increased tipping fees and transportation costs could completely outweigh all other benefits of RDF co-firing.

5.3.4 Excess Air and RDF Quality

RDF quality does not impact the SIR as significantly as the previously discussed model inputs. However, disadvantages to low quality RDFs are numerous and cumulative. High moisture content RDF will adversely affect storage, handling, and combustion efficiency. High ash content will increase the potential for slagging and will increase O&M costs. It could also affect capital costs if upgrading the ash handling system is determined to be necessary. Minimizing ash and moisture content will improve the heating value of the fuel and will enhance the ability to co-fire at higher substitution ratios. Better fuel quality will also result in more stable combustion and improved boiler efficiency. Although premium quality RDFs are technically achievable, the ability to negotiate a contract for a high quality RDF at an advantageous price has not been proven.

Compared to the other model inputs, the value for the excess air level has minimal impact on the SIR. However, it is widely recognized that appropriate control of the excess air levels is advantageous to overall boiler efficiency and economics.

5.4 RECOMMENDATIONS

Changes in certain economic conditions will impact the feasibility of RDF co-firing. It is therefore recommended that the following factors be monitored on an annual basis:

- Conventional fuel cost
- MSW disposal cost
- MSW generation rate
- Ash disposal costs
- RDF production: Markets
  Prices

If these factors change such that the model yields an acceptable SIR, a site specific analysis should be done. This analysis would examine factors that are not covered by the model, such as the ability to balance the steam demand to maximize the co-fire ratio, determining the composition and quantity of base-generated solid waste, and local factors such as ash and MSW costs and regulations.

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